FINAL DRAFT REPORT

EVERGLADES PROTECTION PROJECT

Contract C-3051, Amendment 6

ANALYSIS AND DEVELOPMENT OF CHEMICAL TREATMENT PROCESSES

Submitted to:

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

June 1, 1993

BROWN AND CALDWELL CONSULTANTS

In Association With:

Mock, Roos & Associates, Inc.

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EXECUTIVE SUMMARY

Background

The South Florida Water Management District (District), in its adoption of the Surface Water Improvement and Management (SWIM) Plan for the Everglades Agricultural Area (EAA) committed to evaluate alternative technologies to the recommended treatment system using Stormwater Treatment Areas (STAs). Brown and Caldwell, under Contract C-3051, "Evaluation of Alternative Technologies, Everglades Protection Project," has been systematically evaluating the numerous alternative technologies to determine whether any of these technologies have the potential to be more effective, both from a technological and economical standpoint, to the current SWIM Plan. The current SWIM Plan proposes a combination of STAs and reduced phosphorus discharges from agricultural lands in the EAA through on-farm best management practices (BMPs).

This report, prepared under Amendment No. 6 to Contract C-3051, is the fourth in a series of reports related to the evaluation of alternative treatment technologies. The first report, prepared under Amendment No. 1, involved the development of Phase I Evaluation of Alternative Treatment Technologies to evaluate the various technologies. The second report, prepared under Amendment No. 2, involved the initial screening of the various treatment technologies that had been proposed to the District for consideration . The third report, Amendment No. 4--Phase II Evaluation of Alternative Treatment Technologies, further investigated and compared the top three rated technologies from the Phase I evaluation: (1) STAs, (2) direct filtration, and (3) chemical treatment followed by sedimentation.

At each level of analysis, Brown and Caldwell compared each technology on both a quantitative and a qualitative basis. Amendment No. 6 uses testing of EAA waters to determine estimated dosage rates and conditions for the chemical treatment technologies. The bench scale testing of actual EAA waters allows the incorporation of these results into a revised preliminary design and costs analysis. Direct filtration treatment and costs is determined for both high-rate (11 gpm/ft^2) and low-rate (6 gpm/ft^2) surface loading rates on the filters. In addition, it was determined that flow equalization allows for a reduction in treatment plant capacity and lengthens the time of treatment plant utilization. The effects of the estimated particulate phosphorus reduction due to flow equalization is presented.

Scope of Amendment No. 6 Evaluation

This report comprises the Final Draft Report of Amendment 6, Contract C-3051, "Evaluation of Alternative Treatment Technologies." As shown in the Table of Contents, the report is made up of five technical memoranda. These memoranda address the following tasks as defined in the original scope of services:

Technical Memorandum No. 1 (Tasks 2-4). Bench scale testing methods and results, raw water quality data, and sludge testing results.

Technical Memorandum No. 2 (Task 8). Daily flow and P load data development. Application of BMP and flow equalization basin reductions to flow and P load data.

Technical Memorandum No. 3 (Task 9). Flow equalization/direct filtration treatment plant sizing optimization. Conceptual unit process design (basis of design table).

Technical Memorandum No. 4 (Task 9). Preliminary cost estimates of direct filtration technology including capital, O&M, and 20-year present worth estimates.

Technical Memorandum No. 5 Sedimentation technology analysis, cost estimates and comparison of sedimentation versus direct filtration.

Bench scale testing of runoff waters (Technical Memorandum No.1) from the Everglades Agricultural Area (EAA) is followed by daily flow and P load data development (Technical Memorandum No. 2). After treatment plant and flow equalization basin sizing is completed, the conceptual unit design is presented (Technical Memorandum No. 3) followed by capital, O&M, and present worth cost estimates (Technical Memorandum No. 4). In the final memorandum, (Technical Memorandum No. 5), sedimentation technology analysis and cost estimates are presented, along with a discussion of sedimentation versus direct filtration. Pertinent appendices are contained at the end of each technical memorandum, such that each memorandum is a stand-alone document.

In addition, the report contains a process flowsheet diagram and general site layouts of the direct filtration treatment process (Technical Memorandum No. 3).

<u>Results of Amendment No. 6 Evaluation</u>

Complete results and discussion of bench-scale test results and their implications are presented in detail in Technical Memorandum No. 1. While all of the results of the bench scale testing are considered important to chemical treatment and direct filtration technology analysis, the following is an abbreviated list of these results:

1. Chemical additives evaluated were to determine the optimum dosage and conditions under which the most efficient phosphorus removal is realized.

2. The optimum pH for alum treatment in the bench scale testing was about pH 7.0. The optimum pH for iron treatment was approximately pH 7.5. Phosphorus and coagulant residuals were both low in these pH ranges, and solids separations were effective.

3. Alum was the most effective primary coagulant for direct filtration because it could obtain low total phosphorus (7-12 ug/l) and low coagulant residuals (0.5 mg/L) at relatively low Al doses, in the neighborhood of 6 mg/L (0.22 mM). Also, alum produces less chemical sludge than iron compounds at the same molar dosage. Iron compounds could not attain these low P residuals until higher doses were used (about 0.3 mM or 16 mg/L Fe). Whether these iron doses can be accommodated by direct filtration systems needs to be determined by pilot testing. If they cannot, then iron treatment would only be used with sedimentation systems.

4. Increases in chemical dosages, from those assumed in the Amendment No. 4 Report, were due to a higher actual organic content than that assumed in the Amendment No. 4 Report. In other words, waters tested showed higher organic content over surface runoff waters currently treated in Wahnbach, Germany. The revised dosage rates do allow for removal of P to levels realized by the German plant.

5. If lower total phosphorus residuals are needed, or evidence about Al toxicity in water or sludges preclude the use of alum, then iron becomes the favored coagulant. However, relatively high iron doses (>0.3 mM) will be needed to attain low total phosphorus residuals, which may favor the use of sedimentation systems, which are typically not limited by solids loading rates. Also, iron may be required if runoff waters are significantly more concentrated in total phosphorus or other coagulant-demanding substances (algae or dissolved organics, for example) than the runoff waters processed in this study. Pretreatment to reduce coagulant demand would be evaluated in the pilot study. Ferric chloride appears to be a better coagulant than ferric sulfate.

6. Direct filtration achieves low P and coagulant residuals at relatively modest reagent dosages. (Note that filtration is likely to produce somewhat better effluent quality at pilot and full scale than it did at bench scale). Sedimentation usually cannot achieve the same level of effluent quality, even when higher coagulant doses are used. However, sedimentation is simpler than direct filtration, and may be less costly overall. Both alternatives should be tested during the pilot-scale investigation.

7. Use of an anionic polymer produced faster-forming, larger, stronger and discrete floc. These floc were vastly more amenable to filtration and sedimentation than floc generated when no anionic polymer was used. Use of anionic polymers should allow filtration or sedimentation processes to operate at higher rates with better treatment efficiency. Anionic polymers are relatively cost effective, because they are used in small amounts.

Use of a cationic polymer (in conjunction with an anionic polymer) may have improved turbidity removals and reduced coagulant residuals. The cationic polymers should be further investigated to improve reduction of metals.

8. To determine the effects of chemical treatment on the water chemistry, a detailed scan of raw and treated water was conducted. Alum treatment of Batch D (the fourth in a series of grab samples of EAA runoff) water produced significant reductions in total phosphorus and color, moderate reductions in COD and TOC, and minor reductions in DOC and silica. Aluminum and sodium concentrations increased slightly. Iron and manganese concentrations were reduced slightly. Sulfate concentration increased moderately on a mass basis, but increased greatly on a percentage basis. Changes in trace element concentrations could not be measured as they were below the detection limits.

9. Analysis of the sludge generated during alum treatment of Batch D water showed that only chromium, and possibly selenium, had the <u>potential</u> for exceeding the TCLP limits. Current results indicate that it is unlikely that chemical treatment plant sludges are a hazardous waste. Additional tests are needed under pilot plant conditions.

In parallel with bench scale testing of EAA waters, treatment plant sizing in combination with flow equalization of runoff waters was modeled using existing daily flow and phosphorus load data over the 9.75-year period of record 1979 to 1988. Table ES-1 presents the optimal flow equalization basins areas and the corresponding treatment plant capacity as determined by the modeling of daily flows and phosphorus loads over the period of record.

Table ES-1. Flow Equalization Basin/Treatment Plant Capacities

Location	FE Basin Area/Treatment Plant Capacity with FE Basin Reductions[a]	FE Basin Area/Treatment Plant Capacity without FE Basin Reductions
Basin S-5A	2,700 acres, 200 MGD	2,800 acres, 260 MGD
Basin S-6	1,700 acres, 150 MGD	1,700 acres, 190 MGD
Basin S-7	1,400 acres, 130 MGD	1,700 acres, 190 MGD
Basin S-8	2,400 acres, 340 MGD	2,800 acres, 450 MGD

[a] 35 percent reduction in particulate P and TSS assumed due to flow equalization effects.

As detailed in Technical Memoranda No. 2 and No. 3, these data were incorporated into a preliminary basis of design for direct filtration treatment plants for each of the four major drainage basins of the EAA: Basin S-5A, S-6, S-7 and S-8. Once treatment plant sizing and primary process trains were established, capital, operations and maintenance (O&M), and 20-year present worth costs were calculated. Table ES-2 presents a summary of the 20-year capital cost estimates derived from the work performed in Amendment No. 6. The costs were developed for the treatment plant capacities and flow equalization basin sizing using the 35 percent reduction in particulate P and TSS in the flow equalization basin.

Table ES-2. Estimated Range in 20-year Present Worth Cost for Flow Equalization/Direct Filtration[a]

Location	High Rate[b]	Low Rate
Basin S-5A	$110,423	$115,236
Basin S-6	75,829	82,401
Basin S-7	85,360	90,338
Basin S-8	129,343	143,269
Totals	$400,954	$431,243
$/Pound of P Removed	109	116

[a] Thousands of June 1993 dollars.
[b] Based on an assumed 35 percent reduction in TSS and particulate P in the FE basin.

Table ES-2 also shows the cost of phosphorus removal, expressed in dollars per pound of phosphorus removed and total present worth cost. This cost is obtained by dividing the present worth by the mass of phosphorus removed over the 20-year period.

TECHNICAL MEMORANDUM NO. 1

11-7518-03

Draft Revision May 10, 1993

TO: FILE

FROM: C. ZACHARY FULLER, P.E.,
DOUGLAS T. MERRILL, PhD, P.E.

SUBJECT: BENCH-SCALE TEST RESULTS AND THEIR IMPLICATIONS, EVERGLADES PROTECTION PROJECT

This memorandum details test results from the bench-scale tests conducted in Florida during the period March 30 through April 9, 1991. The tests were conducted by Doug Merrill and Luke Mulford of Brown and Caldwell (BC) at DB Environmental Laboratories (DBEL) in Rockledge, Florida. DBEL did most of the chemical analyses.

Also presented are some preliminary results from parallel experiments on a simulated Everglades water performed by Dr. Heinz Bernhardt and Mr. Helmut Schell in Germany. Their work tends to confirm the test results obtained in Brown and Caldwell experiments with real Everglades waters.

Test Objectives

The overall objective was to acquire specific data that could be used to develop preliminary designs and costs for direct filtration and chemical treatment systems in the Everglades. It is planned that this information will be updated with data developed during subsequent pilot studies if the decision is made to carry the direct filtration or chemical treatment/sedimentation alternatives forward.

In this memorandum, direct filtration means chemical addition, solids destabilization, flocculation, and filtration in mixed-media beds. Chemical treatment/sedimentation is the same, except that the filter beds are replaced by gravity clarifiers.

The specific objectives of the bench-scale tests were to:

1. Determine the optimum treatment pH for several candidate primary coagulants (alum, ferric chloride, and ferric sulfate).

2. Determine the appropriate range of coagulant dose for the candidate primary coagulants.

3. Select the most efficient of the three coagulants, using the information developed.

4. Compare the performance of the direct filtration and chemical treatment/sedimentation options.

5. Investigate the effect of polymers on enhancing treatment performance.

6. Estimate the effects of treatment on the quality of the finished effluent.

7. Estimate sludge production.

8. Estimate sludge composition, for the purpose of assessing the sludge's potential to be a hazardous waste.

Where possible, responses are formulated to answer the concerns of individuals who are critical of treatment systems that use chemicals. For example, Dr. Ron Jones of SAGE, made the following points about iron treatment systems in his letter to Dr. Peter Rhoads of the South Florida Water Management District (SFWMD), dated February 27, 1993. In Dr. Jones' opinion, iron systems:

1. Remove phosphorus (P) without removing N, causing a shift in the N/P ratio that could upset the downstream flora and fauna.

2. Remove vital micronutrients from the system.

3. Have the potential to add extremely high concentrations of soluble iron to the water.

4. Alter the water's anion balance.

5. Remove dissolved organic materials from the water.

Procedures

The Florida water samples were collected from Pump Station S-5A as follows:

1. Sample A (60 gallons) was taken from the inlet of Pump Number 3, south side of the intake bell) at 10:30 A.M. on Monday, March 29, 1993. No other pumps were running.

2. Sample B (30 gallons) was taken from the inlet of Pump Number 1, south side of the intake bell, at 12:00 A. M., Wednesday, March 31, 1993. Pump Number 2 was also running.

3. Sample C (30 gallons) was taken from the inlet of Pump Number 2, north side of the intake bell, on Friday, April 2, 1993. Pump Number 1 was also running.

4. Sample D (15 gallons) was taken from the Inlet of Pump Number 1, north side of the inlet bell, on Thursday, April 8, 1991. Pump Number 2 was also operating.

The pumps were being operated to reduce Lake Okeechobee stages, which were above the desired level.

Samples A, B, and C were stored in 55-gallon polyethylene drums until ready for processing. The lag period between collection and processing was often several days. Sample D was stored in 5-gallon poly carbonate bottles, and processed within a few hours after collection. Rapid testing of Sample D was conducted to address concerns that sample treatability might change with storage. No preservatives were added to any of Samples A, B, C, or D. They were kept at room temperature until ready for processing.

All treatment chemicals were made up fresh each day, using commercial-grade chemicals as the stock solutions. The concentrations of the reagents as introduced to the water were:

1. Alum solution, 0.1 M (2700 mg/l, as Al).

2. Ferric chloride and ferric sulfate solutions, 0.1 M (5580 mg/l, as Fe).

3. Sulfuric acid and sodium hydroxide solutions, 0.3 N.

4. Cationic polymer, Magnifloc 581 C (American Cyanamid), 0.1 percent solution.

5. Anionic polymer, Boliden Intertrade TC 308, 500 mg/l.

Testing was carried out using procedures described by Hudson and Wagner[1] for jar testing. Prior to testing, the water was titrated with the coagulant and acid/base to be used to determine acid/base requirements for each specific jar.

To begin, a two-liter square beaker was filled to the mark with the test water. A Barnant propeller mixer was placed in the test water and operated at a setting of 2.5, which created intense mixing. The mixer speed/speed setting correlation will be developed at a later date. At time = 0 seconds, the desired primary coagulant was added at the tip of the mixer blades via a volumetric pipette. The predetermined amount of acid or base required to achieve the desired pH set point was added immediately thereafter, also at the tip of the impeller. If anionic polymer was to be used, it was added next. Fifteen seconds after adding the anionic polymer, the mixer was shut off, and the two-liter sample transferred to a six-place Phipps and Bird gang stirrer. The sample was then flocculated (slow-stirred) at speeds varying from 17 to 30 rpm for 20 minutes. The pH was trimmed during the flocculation period, if an adjustment was needed.

Two minutes before ending the flocculation phase, a 150 ml sample was withdrawn from the beaker by gravity flow through a stopcock and 1/4-inch Tygon tubing, then immediately filtered through a Whatman Number 40 filter paper, using vacuum. Care was taken to not break up the floc during transfer from the beaker to the filter. The filtrate was later analyzed for turbidity and other parameters of interest. The Whatman 40 filter (nominal pore size 8 microns) is reported to produce about the same or slightly poorer effluent quality as pilot- and full-scale deep-bed granular media filters[2]. Filtration through the Whatman 40 filter thus simulated the direct filtration process.

The flocculation phase was then ended by removing the stirring blades from the test solution. Once agitation stopped the solids began to settle. Samples of the supernatant were withdrawn from the stopcock (which was located 8.7 cm below the water surface) at 1, 2, 5, and 10 minutes after settling was begun. The samples were later analyzed for turbidity and other parameters of interest. The sample quality is reported to corresponded to the quality of water from an ideal settler operating at overflow rates of 3000, 1500, 600, and 300 gallons per day per square foot of surface area[1].

The procedure was modified slightly if a cationic polymer was to be used. The cationic polymer was added first in the chemical addition sequence, and it was allowed to rapid mix for 30 seconds before the primary coagulant and acid or base were added. This mixing period provided time for the polymer to interact with the runoff water solids and reduce their charge. After the metallic coagulant and acid or base was added, the beaker was switched to the gang stirrer and flocculated for 5 minutes. It was then returned to the rapid mixer, where the anionic polymer was added at reduced speed (setting of 1). The beaker was then returned to the gang mixer and flocculated for 20 minutes. Filtration and settling were then carried out as described above.

Limited sets of chemical analyses (turbidity, P, coagulant residuals) were made for most experiments to minimize the bench scale testing costs. A more extensive set of analyses was made for Batch D waters before and after alum treatment. The purpose of this test was to estimate direct filtration-caused changes in a wide range of water quality parameters. The large volume of treated sample needed for these analyses could not be created by direct filtration, because Whatman 40 filters have very limited filtering capacity. Instead it was created by settling seven identically-treated two-liter samples, then combining the settled supernatants in one large bottle. The combined sample was allowed to sit overnight, and the supernatant siphoned away from the remaining amount of solid residue the next day. Long settling times and the extra sedimentation step produced a settled finished water similar in quality to that produced by direct filtration.

Settled solids from the Batch D were collected, dried, and weighed to estimate solids production. These solids were then analyzed for components listed in the Toxicity Characteristics Leaching Procedure (TCLP) to assess the potential for the sludge to be a hazardous waste. The TCLP is a federal procedure used to determine if a sludge is a hazardous waste.

DBEL analyzed the samples for all parameters of interest for which it had state certification.

Duplicate analyses and spike recoveries were made frequently to ensure analytical integrity. In addition, the maximum detection limit for phosphorus was established using coagulated and settled water from Sample A. DBEL subcontracted all analyses for which it did not have state certification.

Results

The text that follows discusses the results and interprets them.

Raw Water Quality. Table 1-1 shows concentrations of selected water quality parameters for the four raw waters as well as historical average concentrations for those parameters for samples collected from Pump Station S-5A. The latter data were obtained from the SFWMD Oracle Data Base, and covered the period June 1974 through October 1992. Note that the data base includes both flow and non-flow samples.

Batch A was the first water sample collected, and most of the experiments to define optimum water chemistry conditions were conducted with it. Note that this water is rather dilute compared to S-5A "average" water. Samples B, C, and D resemble S-5A more closely, but are still somewhat dilute.

Note that:

1. Phosphorus in the particulate form (total P minus total dissolved P) comprised a major portion of total P in the samples taken (42 to 63 percent). Note: The term "dissolved" in this memorandum refers to material passing an 0.45 micron membrane filter. The term "filtered" is used to identify the finished water from jar testing after it has passed through a Whatman 40 filter paper in simulation of a deep bed filter.

2. The concentration of dissolved total P was lower in samples A, B, C and D than in the S-5A "historical average" water.

3. Samples A, B, C and D also had less alkalinity, calcium, magnesium, chloride, and sulfate concentration with a higher pH than S-5A "historical average" water.

Effect of Polymer-Part I. Reproducible filtration and reasonable sedimentation was not obtained until the chemical treatment program was augmented with an anionic polymer Boliden Intertrade's TC 308. This polymer is identified as a polyacrylamide with a "40 percent mole charge."

The polymer's immediate effect was visually identified. Without it, the floc was weak, small, diffuse, and took a long time to form. When the polymer was used, the floc formed immediately upon flocculation (although they did improve in appearance with increased flocculation time up to 10 minutes), and they increased in size, exhibiting a highly-clarified liquid between them. The floc was very strong, as evidenced by the fact that the flocculation speed was increased up to approximately 90 rpm without disrupting or shearing the floc. This action reduced the floc size and appeared to make it more dense.

Table 1-1 Analyses of Untreated Water

Parameter	Batch A	Batch B	Batch C	Batch D	Pump station 5-5A historical average
Total P, µg/L	74	111	147	120	150
Total dissolved P, µg/L	43	46	56	44	88
Total reactive P, µg/L	18	53	70	55	87
Dissolved reactive P, µg/L	17	42	58	37	-
Total acid hydrolyzable P, µg/L	45	39	45	39	-
Dissolved acid hydrolyzable P, µg/L	26	<4	<4	5	-
Total organic P, µg/L	11	19	32	26	-
Dissolved organic P, µg/L	<4	<4	<4	<4	23
TKN, mg/L	-	-	-	0.90	3.4
Dissolved TKN, mg/L	-	-	-	0.75	3.1
NH_4-N, mg/L	-	-	-	0.06	0.35
NO_3-N, mg/L	-	-	-		1.61
NO_2-N, mg/L	-	-	-	<0.02	0.08
TOC, mg/L	33.5	21.5	31.2	27.9	-
DOC, mg/L	27.0	20.5	28.6	16.9	33.7
BOD_5, mg/L				1.0	-
COD, mg/L	-	-	-	41	-
True color CPU/L	85	78	80	60	161[a]
pH	7.8	-	8.1	7.6	7.23
Ca, mg/L	58	-	67	45	77
Mg, mg/L	12	-	14	13	26
Alkalinity, mg/L, as $CaCO_3$	140	122	176	102	243
SO_4, mg/L	-	-	-	27.5	77
Cl, mg/L	-	-	-	74	188
Na, mg/L	-	-	-	46	104
K, mg/L	-	-	-	5	5.9
TSS, mg/L	3.5	14.8	25	15	19.4
TDS, mg/L	475	448	618	408	-
Turbidity, NTU	5.5	-	17	12	9

Table 1-1 Analyses of Untreated Water (continued)

Parameter	Batch A	Batch B	Batch C	Batch D	Pump station 5-5A historical average
Total SiO_2, mg/L	-	-	-	7.8	20
Dissolved SiO_2, mg/L	-	-	-	7.6	-
Total Al, mg/L	0.22	1.13	1.17	0.115	-
Dissolved Al, mg/L	-	-	-	<0.03	-
Total Fe, mg/L	0.17	0.53	0.62	0.23	0.30
Dissolved Fe, mg/L	0.08	-	-	0.095	0.04
Total Mo, µg/L	-	-	-	<10	-
Dissolved Mo, µg/L	-	-	-	-	-
Total Mn, µg/L	-	-	-	14	-
Dissolved Mn, µg/L	-	-	-	<5	13
Total W, µg/L	-	-	-	<50	-
Dissolved W, µg/L	-	-	-	<50	-
Total Se, µg/L	-	-	-	<5	-
Dissolved Se, µg/L	-	-	-	<5	-
Total Zn, µg/L	-	-	-	5	-
Dissolved Zn, µg/L	-	-	-	45[b]	32
Total Co, µg/L	-	-	-	<20	-
Dissolved Co, µg/L	-	-	-	<20	1.0
Total Cu, µg/L	-	-	-	<5	-
Dissolved Cu, µg/L	-	-	-	<5	15
Total Hg, µg/L	-	-	-	<2	-
Dissolved Hg, µg/L	-	-	-	-	-
Heterotrophic plate count, CFU/L	-	-	-	17,700	-

[a]Not clear whether Pump Station 5-5A color is total color or true color.
[b]Contamination suspected. It is common for dissolved zinc to exceed total zinc when field filtration is involved.

Floc settling rates were improved dramatically with the addition of 0.5 mg/l of the polymer (Figure 1-1). Filtration results also improved, as evidenced by a significant improvement in filtrate turbidity. The use of this or similar polymers may be the key to being able to operate the filters at high rates. It was determined that verification was needed to ensure that the floc is not sticky, or is so large that it blinds the surface of a deep-bed filter. Flocculation characteristics of floc can be worked out at pilot scale. It does appear that floc size can be controlled by flocculator mixing speed. The faster the speed, the smaller and denser the floc. Small floc may be preferred for filtration, to allow the solids better penetration of the filter bed.

The Boliden product is probably not unique. Similar positive effects on flocculation have been experienced when using other anionic polymers in similar applications.

Effect of pH. The effect of pH was evaluated by holding the primary coagulant and polymer doses constant, and varying the pH across a range of 2.5 units. The tests showed that iron systems (systems using ferric chloride or ferric sulfate) needed pH equal to or greater than about 7.0 to get good solids separations (Figures 1-7 and 1-10) and relatively low dissolved iron residuals (Figures 1-6 and 1-9). The range of good solids separation and low coagulant residual was relatively broad for alum (7.0 to 8.0), see Figures 1-3 and 1-4.

For the coagulant doses tested (Al = 10 mg/l, Fe = 20 mg/l), total dissolved P was effectively removed from solution at all pH values (Figures 1-2, 1-5, and 1-8).

Effect of Coagulant Dose. The effect of coagulant dose was evaluated by varying the dosage while holding the pH fixed at values determined to be appropriate, as determined from the pH experiments described above. These pH values were 7.0 for alum systems and 7.5 for iron systems. The anionic polymer dose was fixed at 0.5 mg/l. Alum results are shown in Figures 1-11 to 1-13, ferric chloride results in Figures 1-14 to 1-16, and ferric sulfate results in Figures 1-17 to 1-19. Table 1-2 summarizes some conditions that might be used in the conceptual analyses of direct filtration and chemical treatment/sedimentation systems.

Comparison of Coagulants. The data on Figures 1-11 to 1-19 have been replotted so that performance of the primary coagulants could be compared directly. Chemical dosages are expressed in millimoles per liter, since the doses used were about the same for all systems when expressed this way.

1. Phosphorus Removal. Ferric sulfate appeared to give the lowest dissolved P residual over the range of chemical doses (Figure 1-20). However, it appears that several of the dissolved P data reported for ferric chloride are erroneously high, possibly due to sample contamination, since they are higher than the P residuals for the filter effluent. They should be lower. It is likely that the dissolved P residuals for ferric chloride and ferric sulfate are similar. It is also believed that the dissolved P residual for the highest alum dose (0.54 mM/l) is erroneously high, also because of contamination.

Table 1-2 Potential Design Conditions

Primary coagulant	Dose, mg/L	Expected treatment residuals					
		P, μg/L		Coagulant, mg/L		Turbidity, NTU	
		filtered	settled	filtered	settled	filtered	settled
Alum	2.5, as Al	30	70	0.5	0.6	2.0	9.0
	6, as Al	10	15	0.4	1.2	1.5	1.8
Ferric chloride	10, as Fe	20	25	1.0	2.3	1.8	2.3
	20, as Fe	10	15	0.1	0.8	0.5	2.0
Ferric sulfiate	10, as Fe	32	50	2.8	7.5	4.8	5.5
	20, as Fe	10	15	1.2	1.3	1.2	1.8

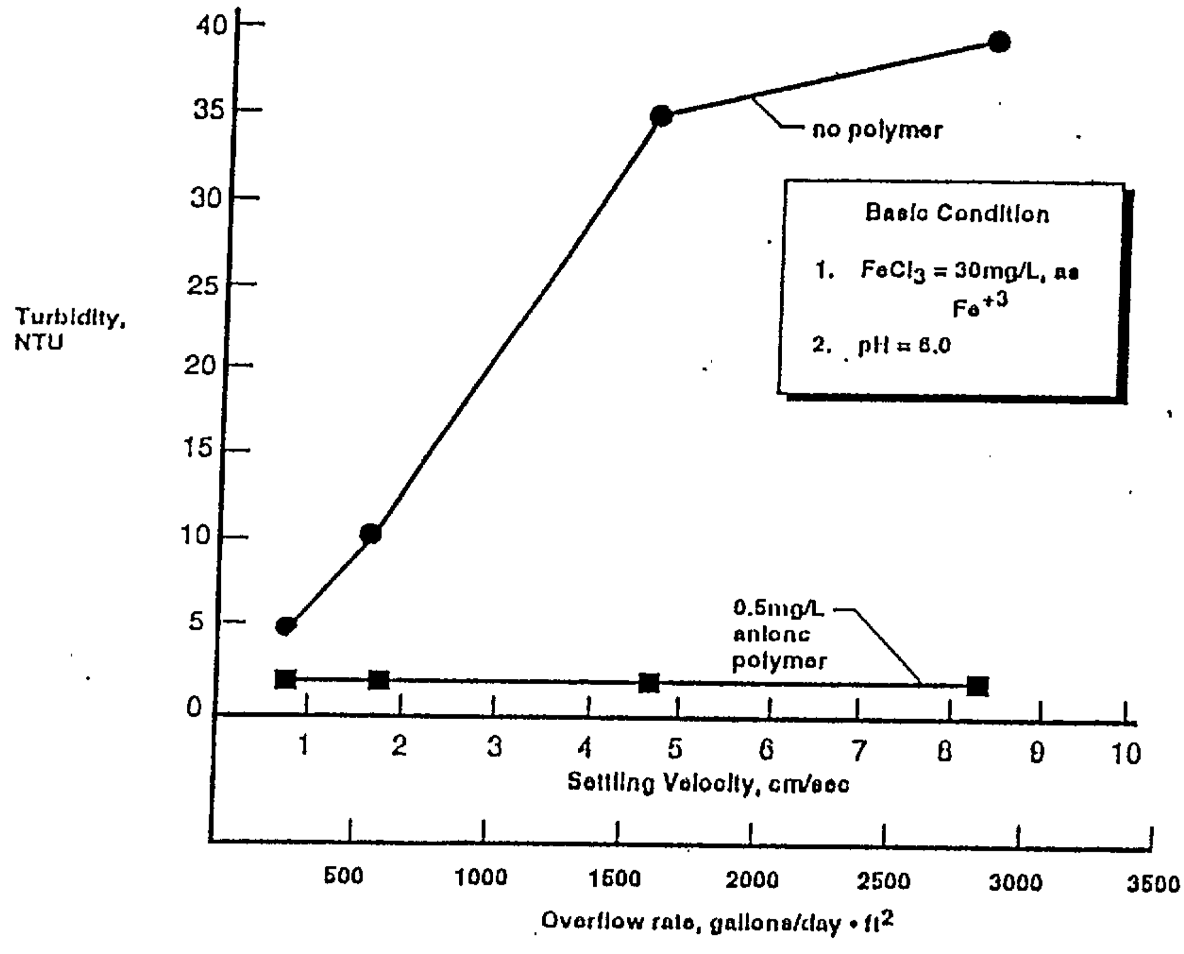


Figure 1-1. Effect of Anionic Polymer on Solids Settling Rates

Conditions: Al dose = 10 mg/L , anionic polymer = 0.5 mg/L

Figure 1-2. Effect of pH on Dissolved Total P Residual: Alum Treatment

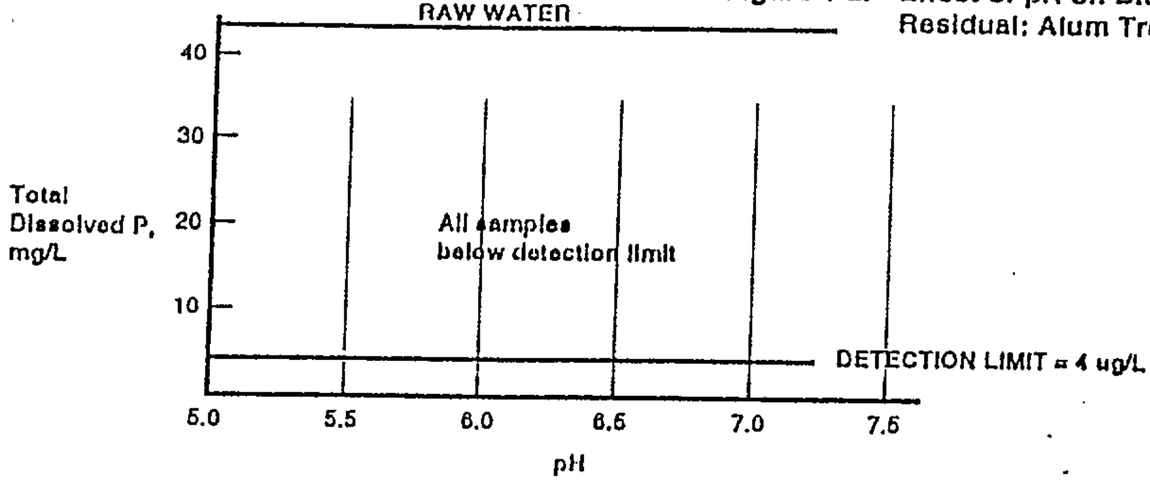


Figure 1-3. Effect of pH on Dissolved Al Residual: Alum Treatment

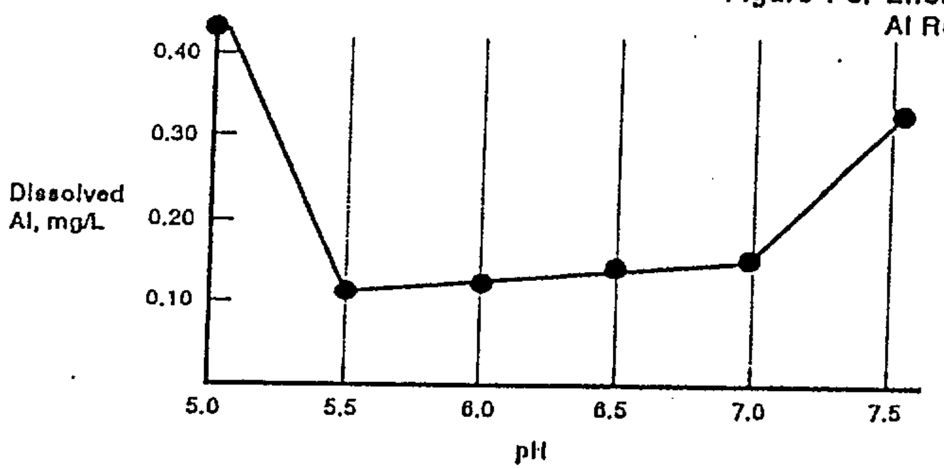
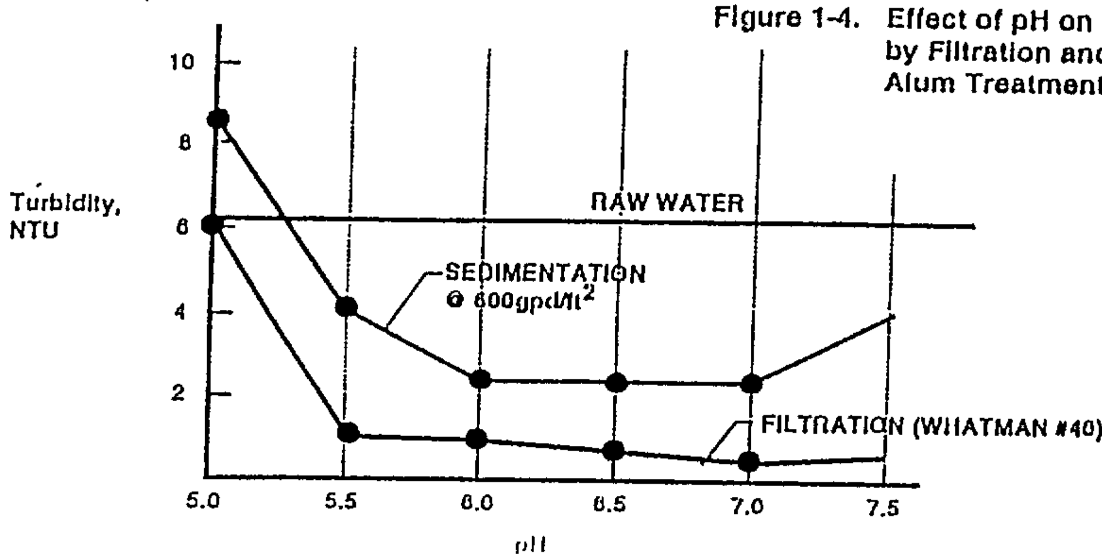


Figure 1-4. Effect of pH on Turbidity Removal by Filtration and Sedimentation: Alum Treatment



Conditions: $FeCl_3$ dose = 20mg/L, as Fe , 0.5 mg/L anionic polymer

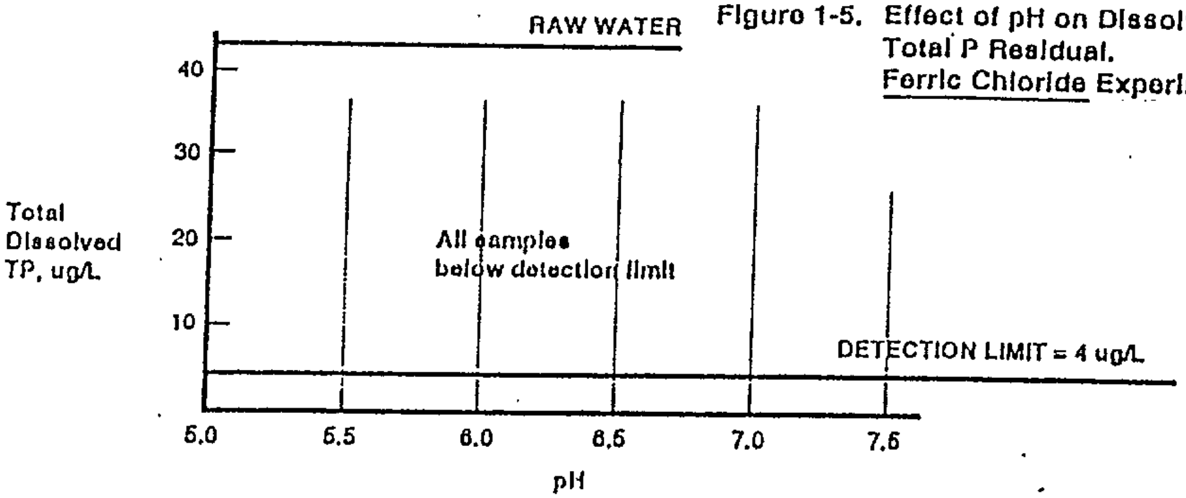


Figure 1-5. Effect of pH on Dissolved Total P Residual. Ferric Chloride Experiments.

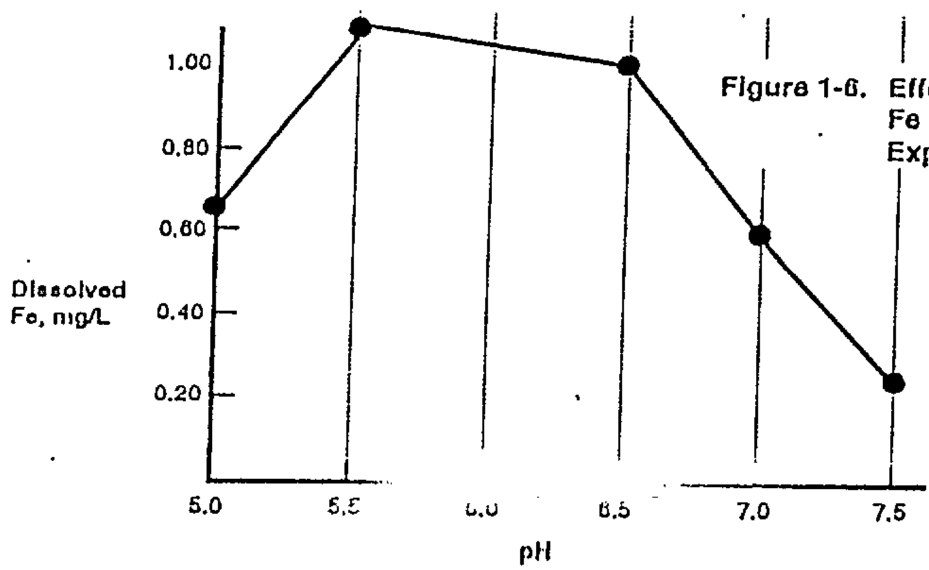


Figure 1-6. Effect of pH on Dissolved Fe Residual. Ferric Chloride Experiments.

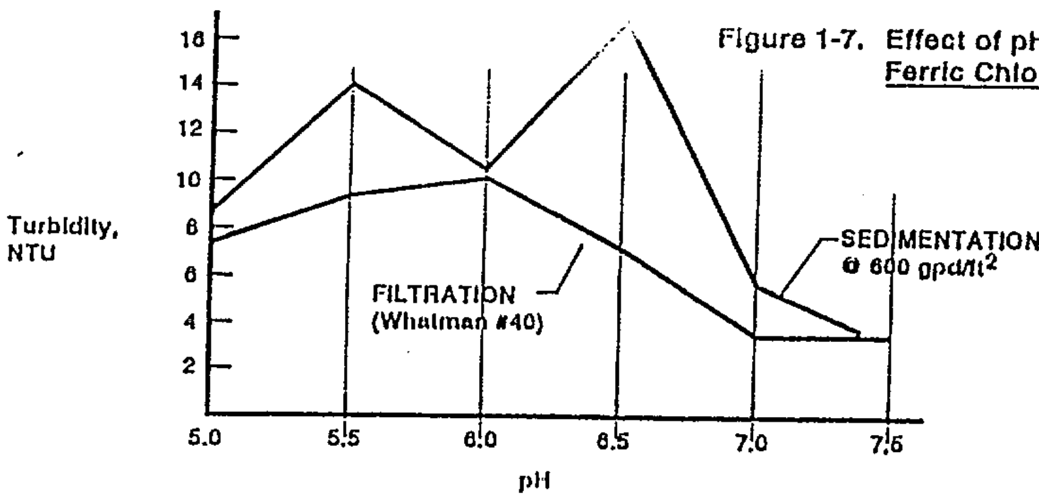


Figure 1-7. Effect of pH on Turbidity. Ferric Chloride Experiments

Conditions: $Fe_2(SO_4)$ dose = 20mg/L, as Fe, anionic polyer = 0.5 mg/L

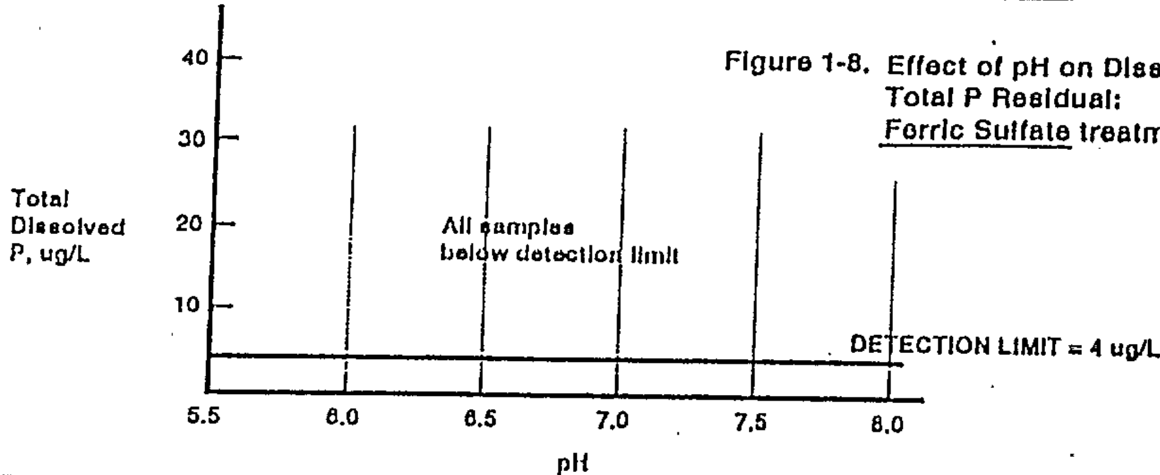


Figure 1-8. Effect of pH on Dissolved Total P Residual: Ferric Sulfate treatment

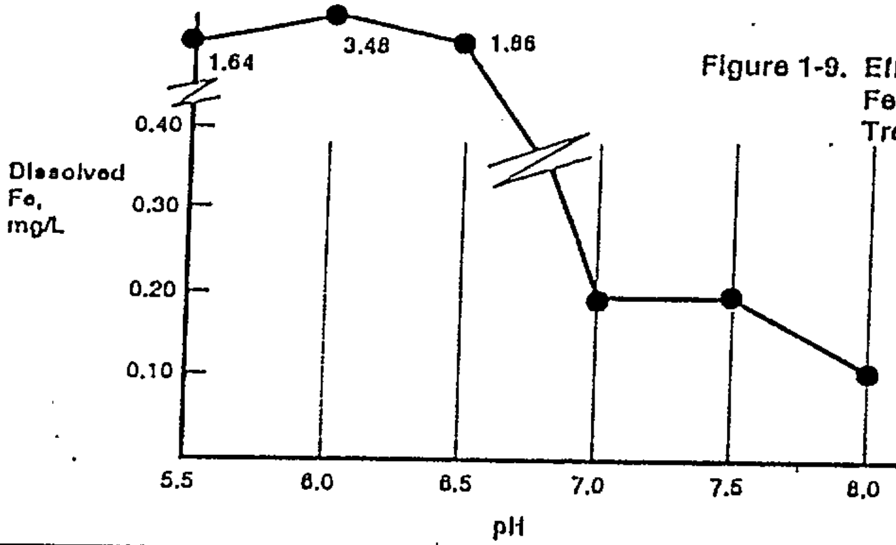


Figure 1-9. Effect of pH on Dissolved Fe Residual: Ferric Sulfate Treatment

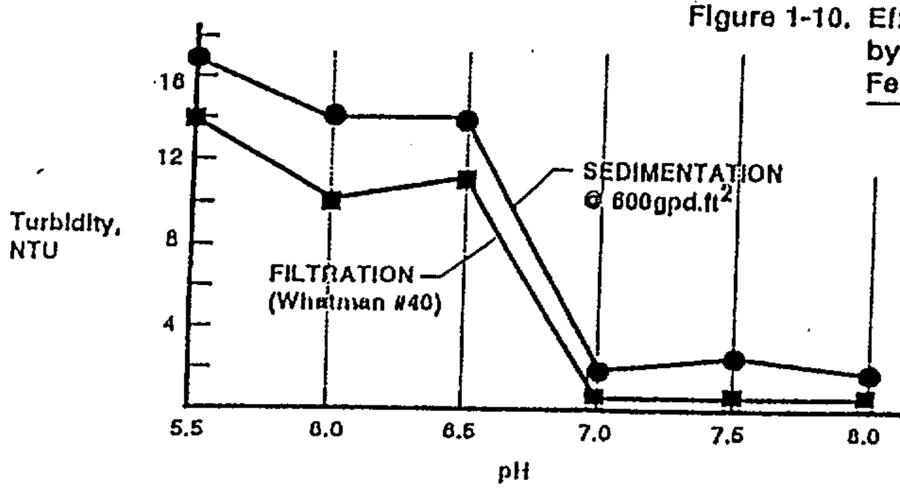


Figure 1-10. Effect of pH on Turbity Removal by Filtration and Sedimentation Ferric Sulfate Treatment

Conditions: pH = 7.0, anionic polymer = 0.5 mg/L

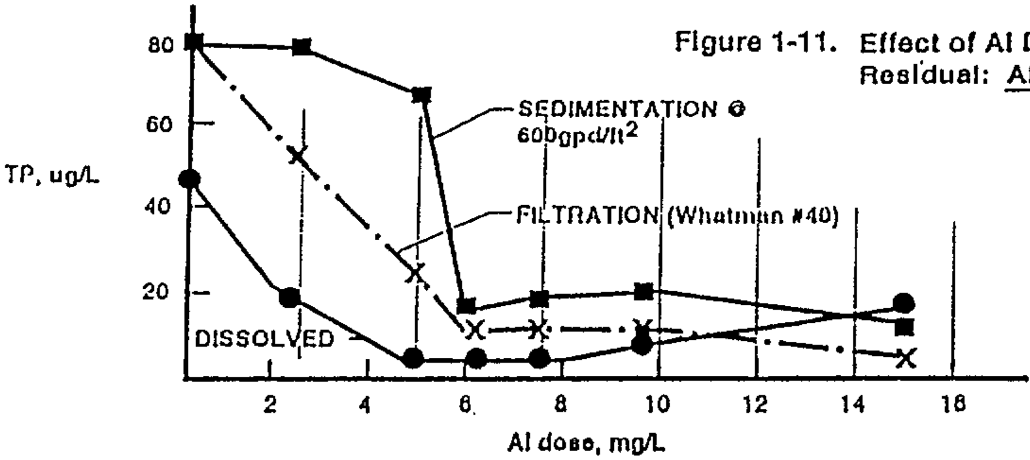


Figure 1-11. Effect of Al Dose on Total P Residual: Alum Treatment

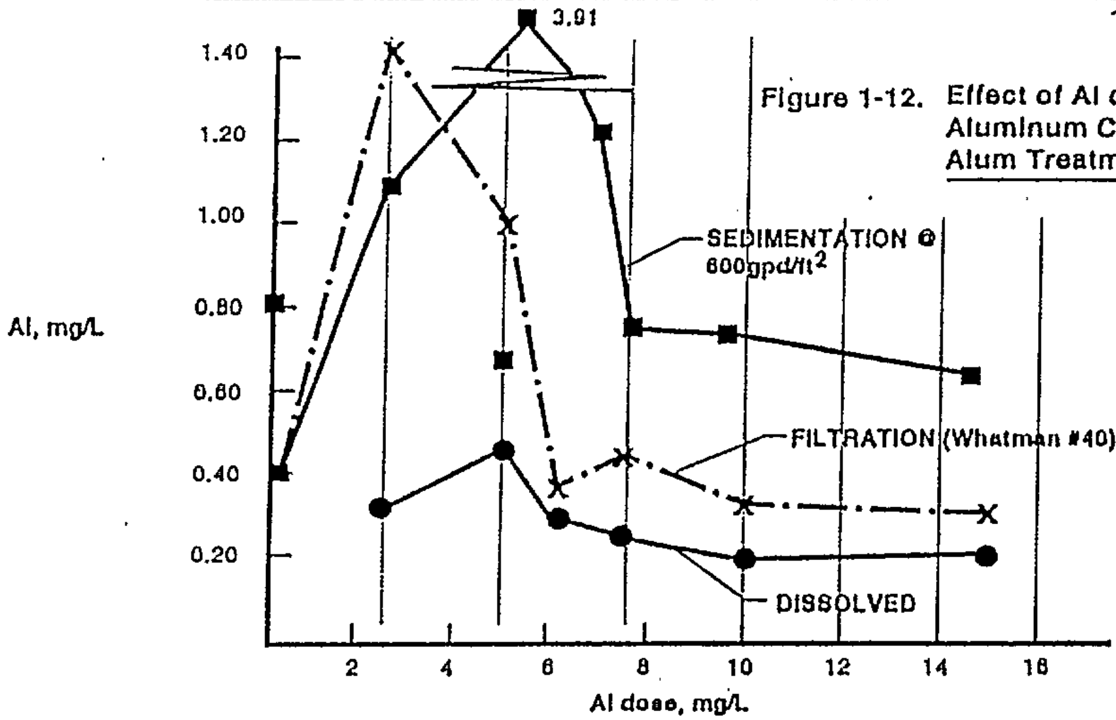


Figure 1-12. Effect of Al dose Dose on Aluminum Concentration: Alum Treatment

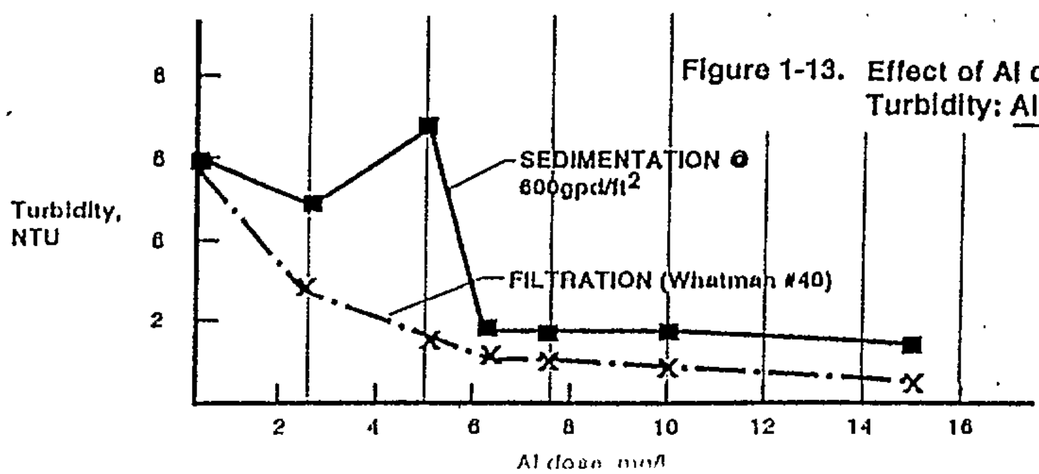


Figure 1-13. Effect of Al dose on Turbidity: Alum Treatment

Conditions pH = 7.5, anionic polymer = 0.5 mg/L

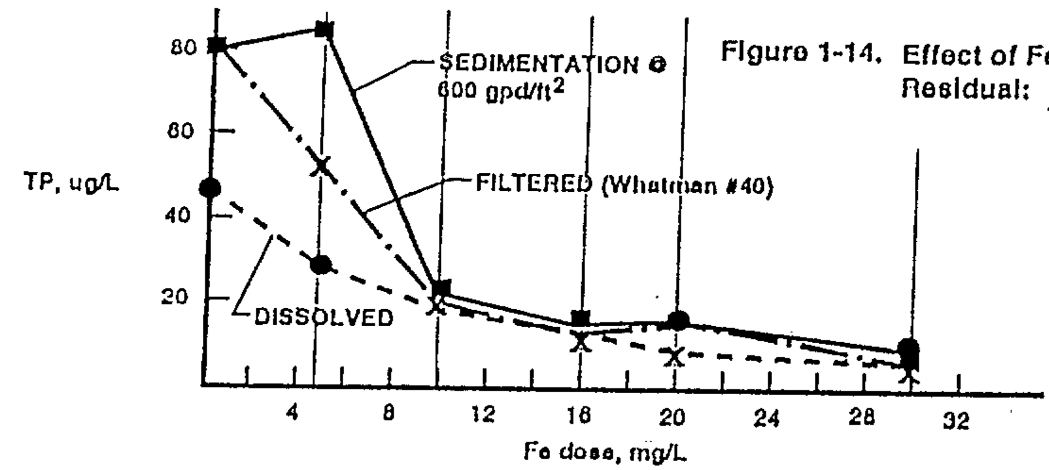


Figure 1-14. Effect of Fe Dose on Total P Residual: Ferric Chloride Experiments

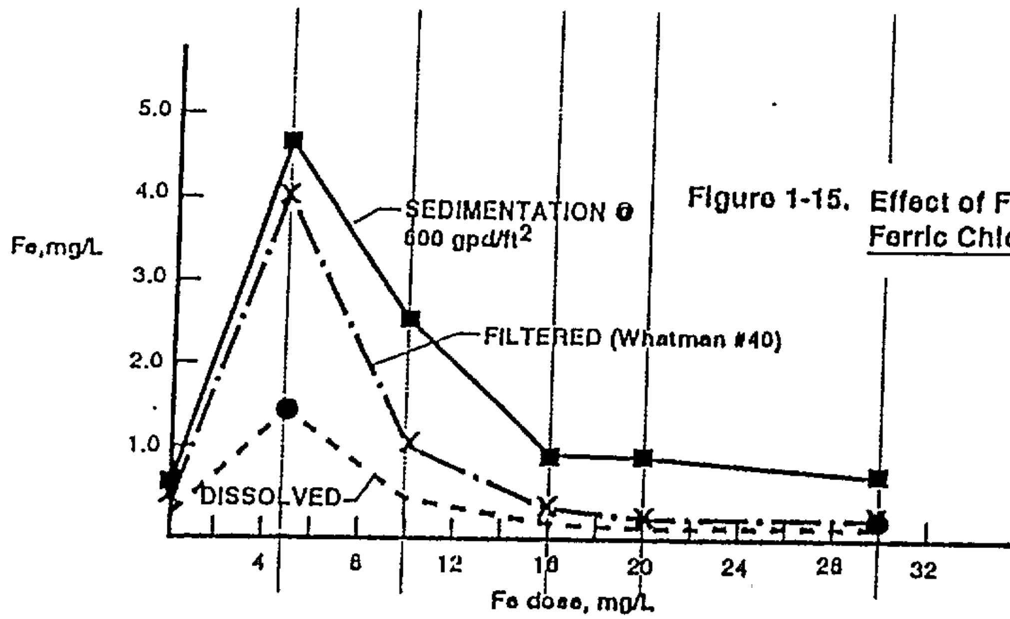


Figure 1-15. Effect of Fe dose on Fe Residual: Ferric Chloride Experiments

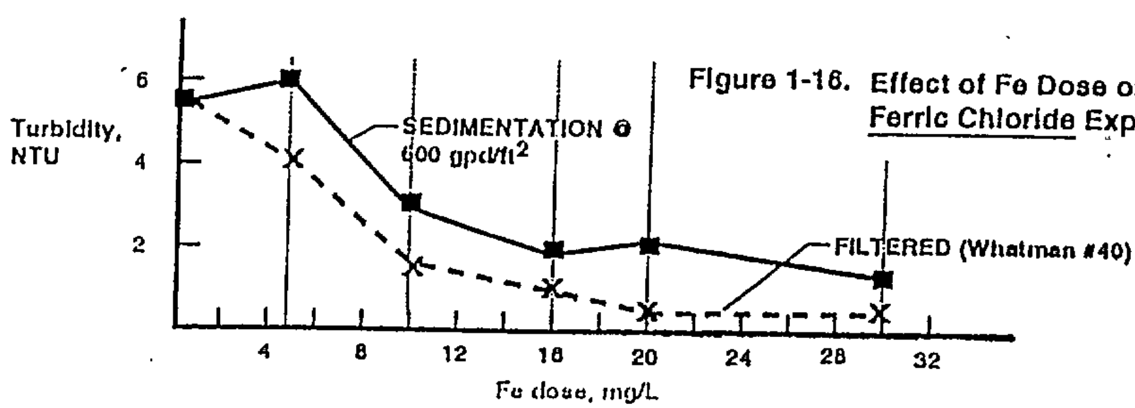


Figure 1-16. Effect of Fe Dose on Turbidity Ferric Chloride Experiments

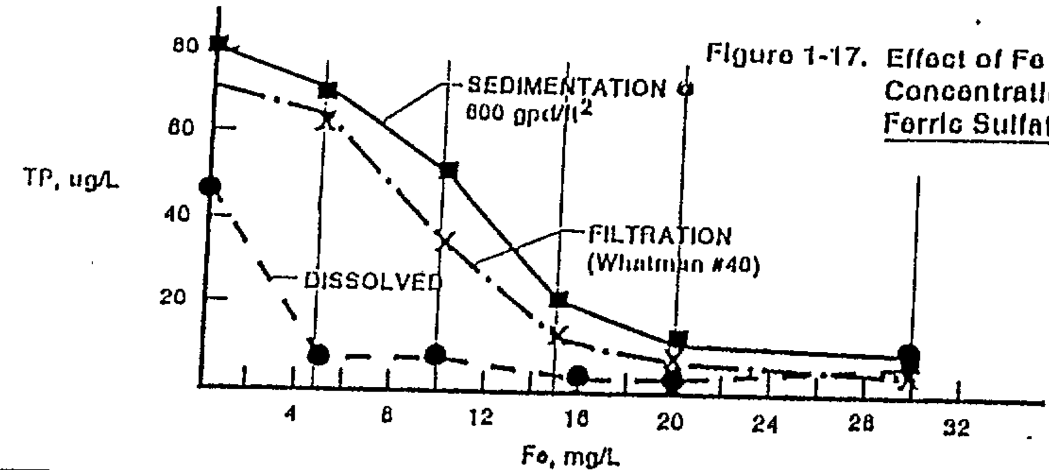


Figure 1-17. Effect of Fe Dose on Total P Concentration: Ferric Sulfate Treatment

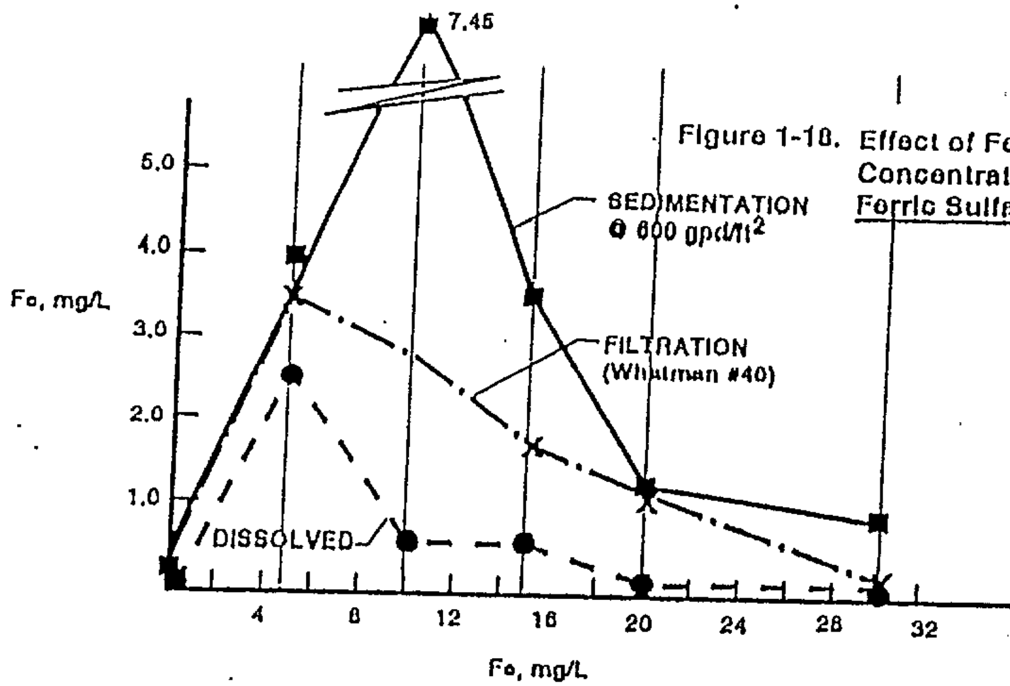


Figure 1-18. Effect of Fe Dose on Fe Concentration: Ferric Sulfate Treatment

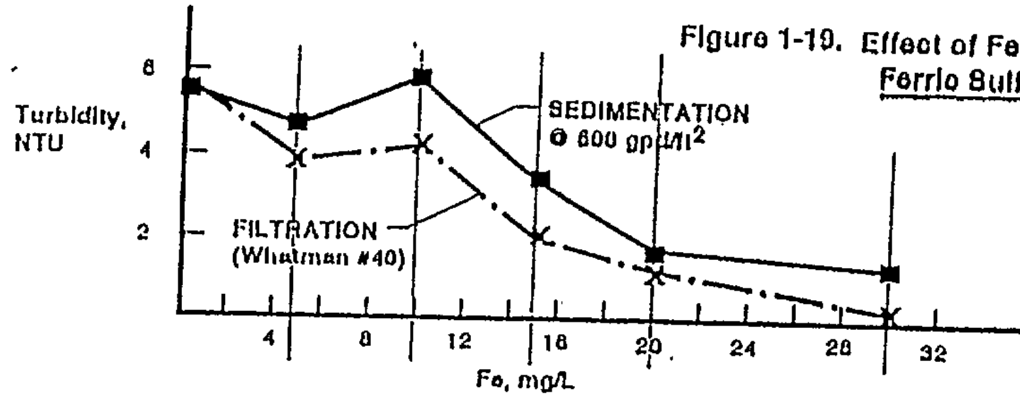


Figure 1-19. Effect of Fe Dose on Turbidity: Ferric Sulfate Treatment

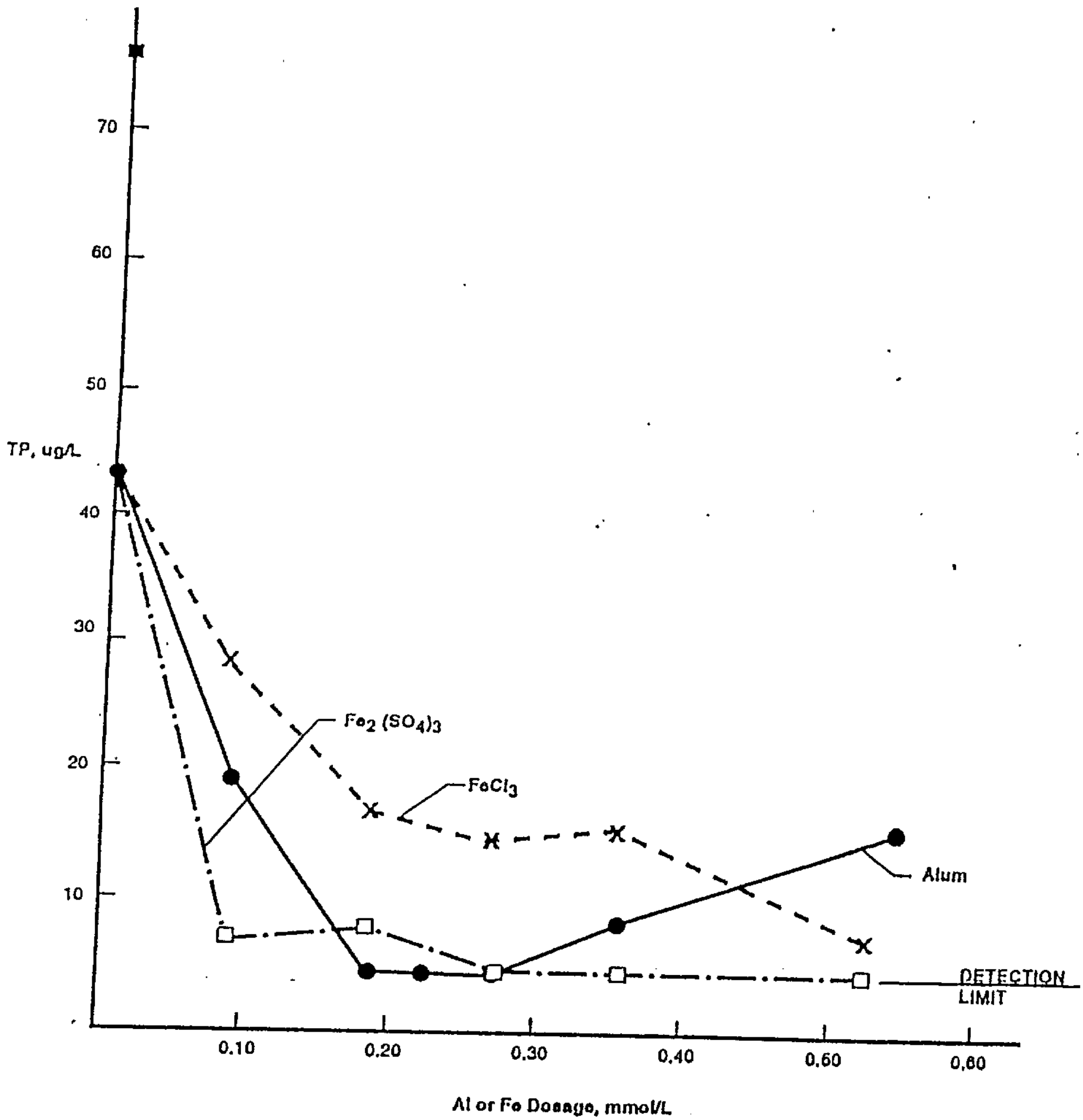


Figure 1-20. Dissolved Total P vs. Aluminum or Iron Dose

Alum gave a low filtered P residual (8 ug/l) at a relatively low dose (0.23 mM), but filtered residuals were lower for the iron compounds as the dosage increased (Figure 1-21). Dr. Bernhardt and Mr. Schell[3] found P residuals to plateau with alum, but not with iron (Figure 1-31), confirming Brown and Caldwell results. The German scientists used a centrifuge to separate the solids instead of a Whatman 40 filter. Alum appears to have the advantage in filtration systems, which cannot tolerate high chemical doses.

Iron appeared to have the advantage in sedimentation systems, achieving lower TP levels than alum once doses exceeded about 0.3 mM (Figure 1-22). Sedimentation systems are not limited by solids loadings, at least in the loading ranges considered in this analysis.

2. <u>Coagulant Residuals.</u> Ferric chloride provided the lowest dissolved coagulant residual, when the residual concentration was expressed in mmole/l (Figure 1-23). This advantage carried through to the filter experiments (Figure 1-24) and sedimentation experiments (Figure 1-25), although the iron residuals for the ferric sulfate and ferric chloride systems approached one another at high iron doses.

   There are valid theoretical reasons for ferric chloride providing lower coagulant residuals than alum or ferric sulfate. The doubly-charged negative counter ion (sulfate) associated with alum and ferric sulfate is readily adsorbed by the positively-charged metal hydroxy complexes and hydroxides responsible for particle destabilization. The singly-charged negative counter ion associated with ferric chloride (chloride) is less readily adsorbed. Adsorption of negatively-charged ions reduces the charge on the positively-charged metal species, making them less effective destabilants of the negatively-charged native solids. Dr. Bernhardt and Mr. Schell[4] demonstrate this point by comparing the dose (expressed as Fe) of ferric chloride and ferric sulfate needed to destabilize a Wahnbach reservoir water (Figure 1-33). The dose required for destabilization is found at the inflection point of the streaming current detector (SCD) titration curves. Clearly less ferric chloride is needed.

   Dr. Jones' statement that treatment systems using chemicals will increase the coagulant residual seems to hold for the low coagulant doses required for direct filtration. However, it may not be valid for ferric chloride systems operating at the higher doses required for sedimentation.

3. <u>Turbidity Removal.</u> Alum and ferric chloride gave the lowest turbidities at low coagulant dose in the filtration experiments, with ferric chloride excelling at higher doses (Figure 1-26). Alum and ferric chloride were also best at low doses in the sedimentation system, with all coagulants performing similarly at higher doses (Figure 1-27).

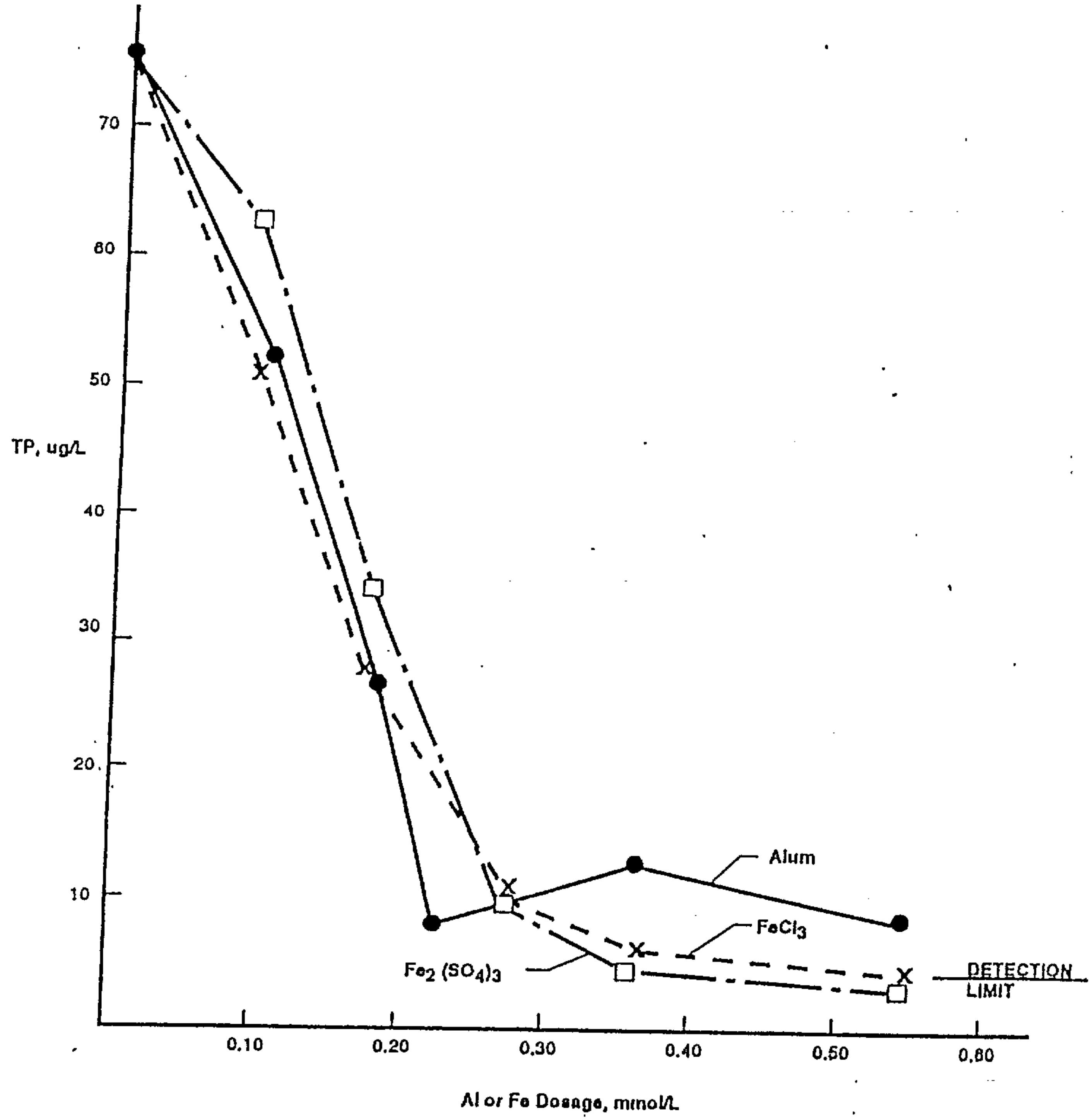


Figure 1-21. Total P Residual vs. Aluminum or Iron Dose, Filtration Experiments

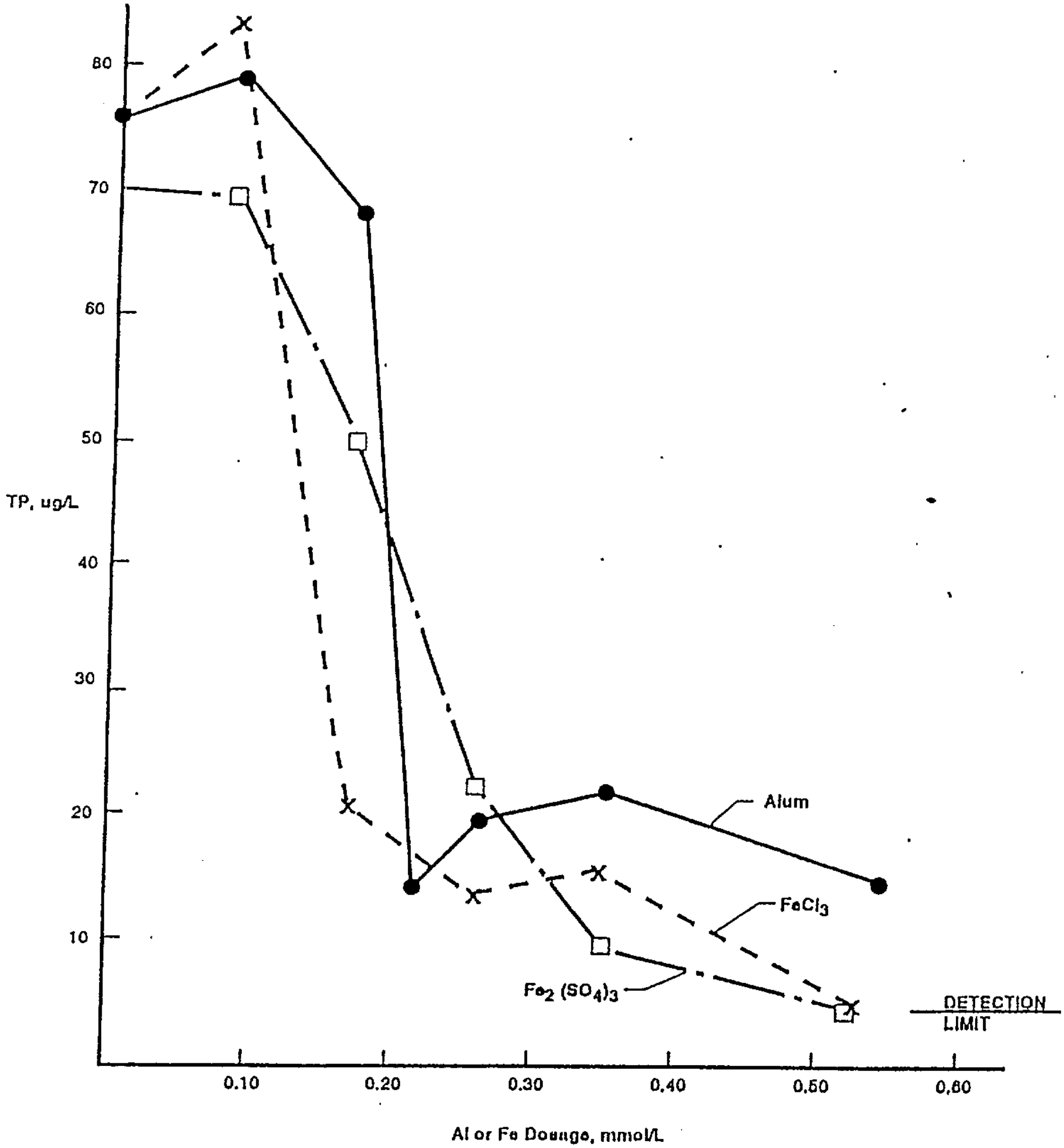


Figure 1-22. Total P Residual vs. Aluminum or Iron Dose, Sedimentation Experiments (Overflow Rate = 600 gpd/ft^2)

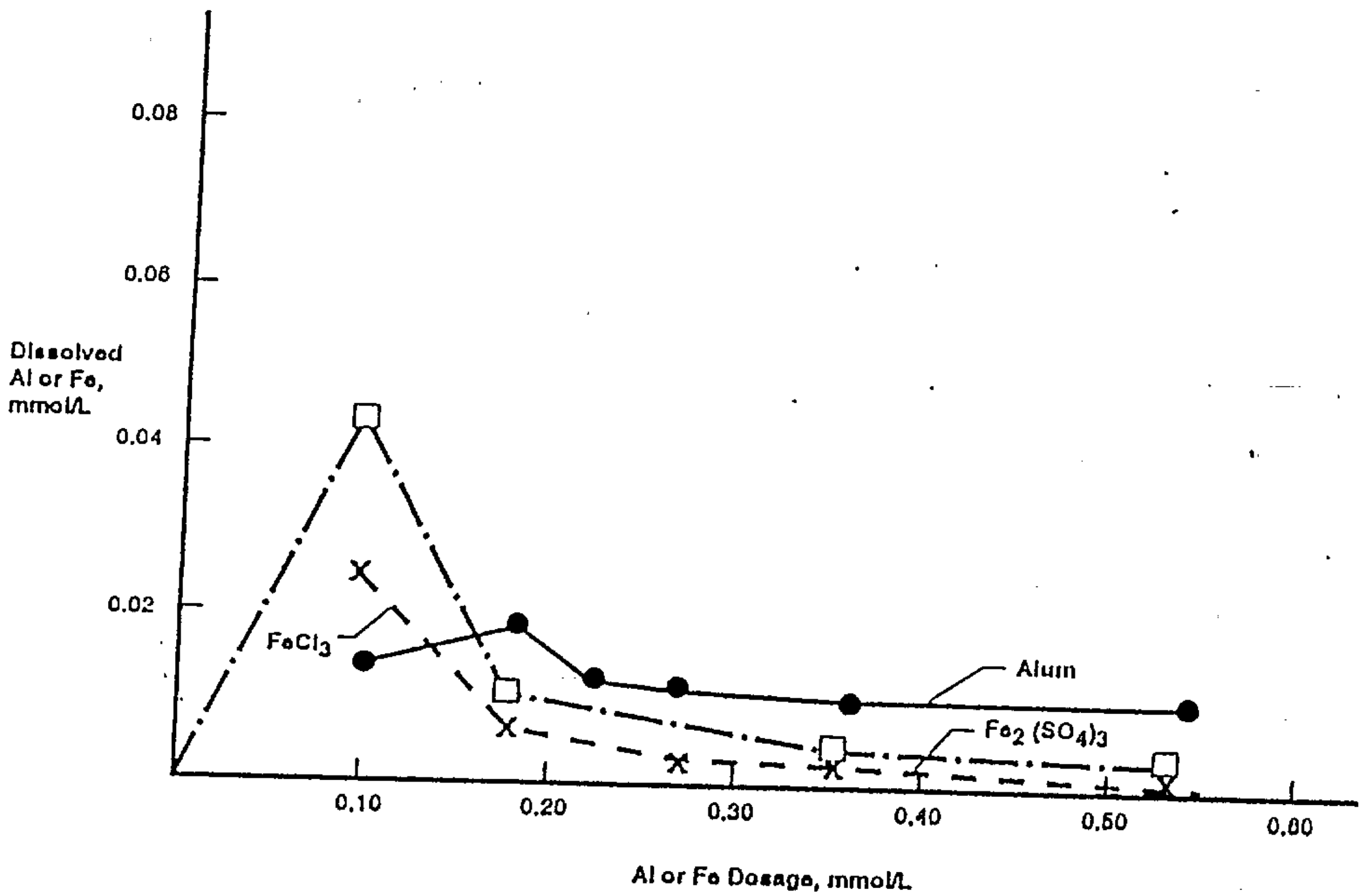


Figure 1-23. Dissolved Al or Fe Residual vs. Al or Fe Dose

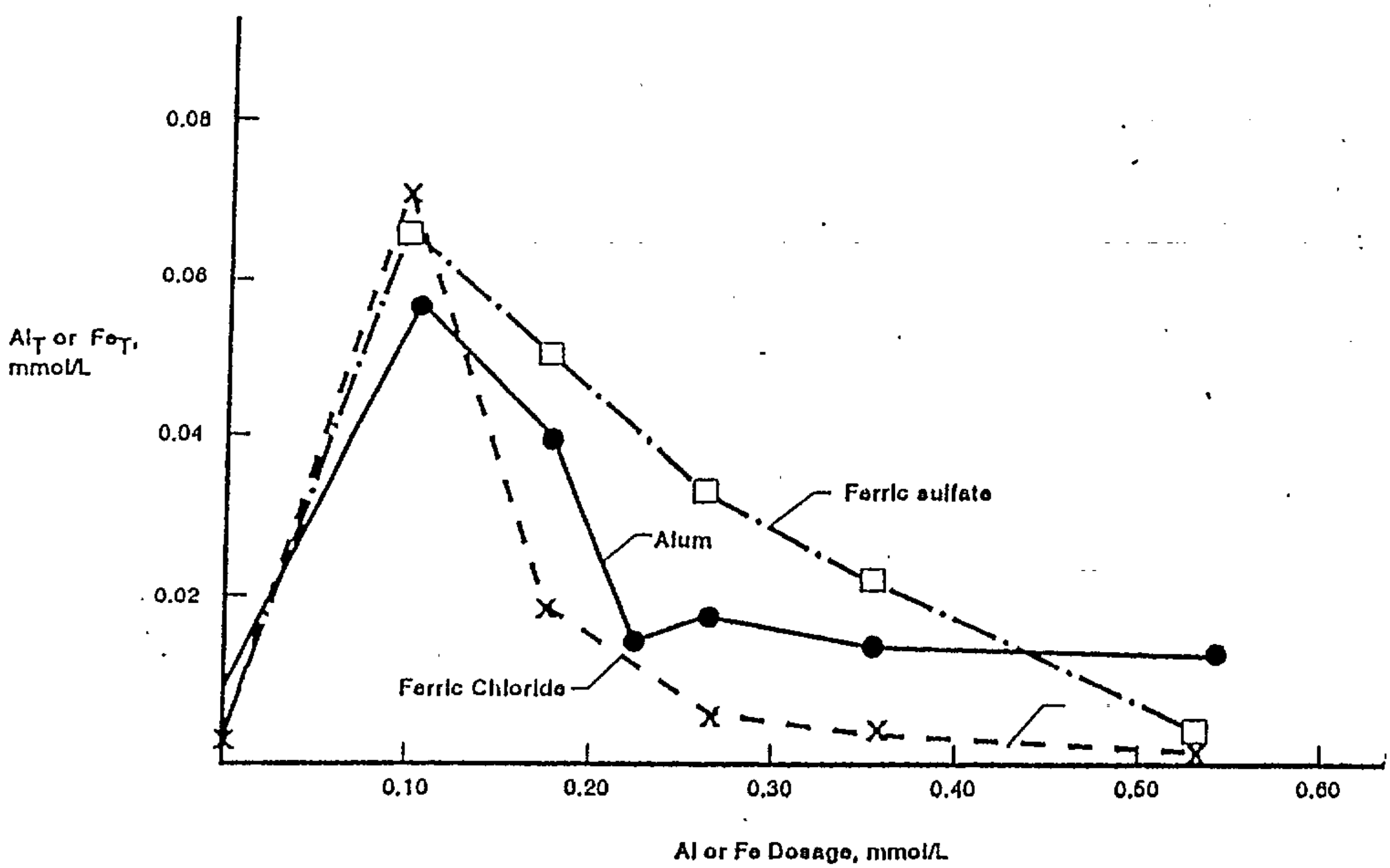


Figure 1-24. Al_T or Fe_T Residual vs. Al or Fe Dose, Filtration Experiments

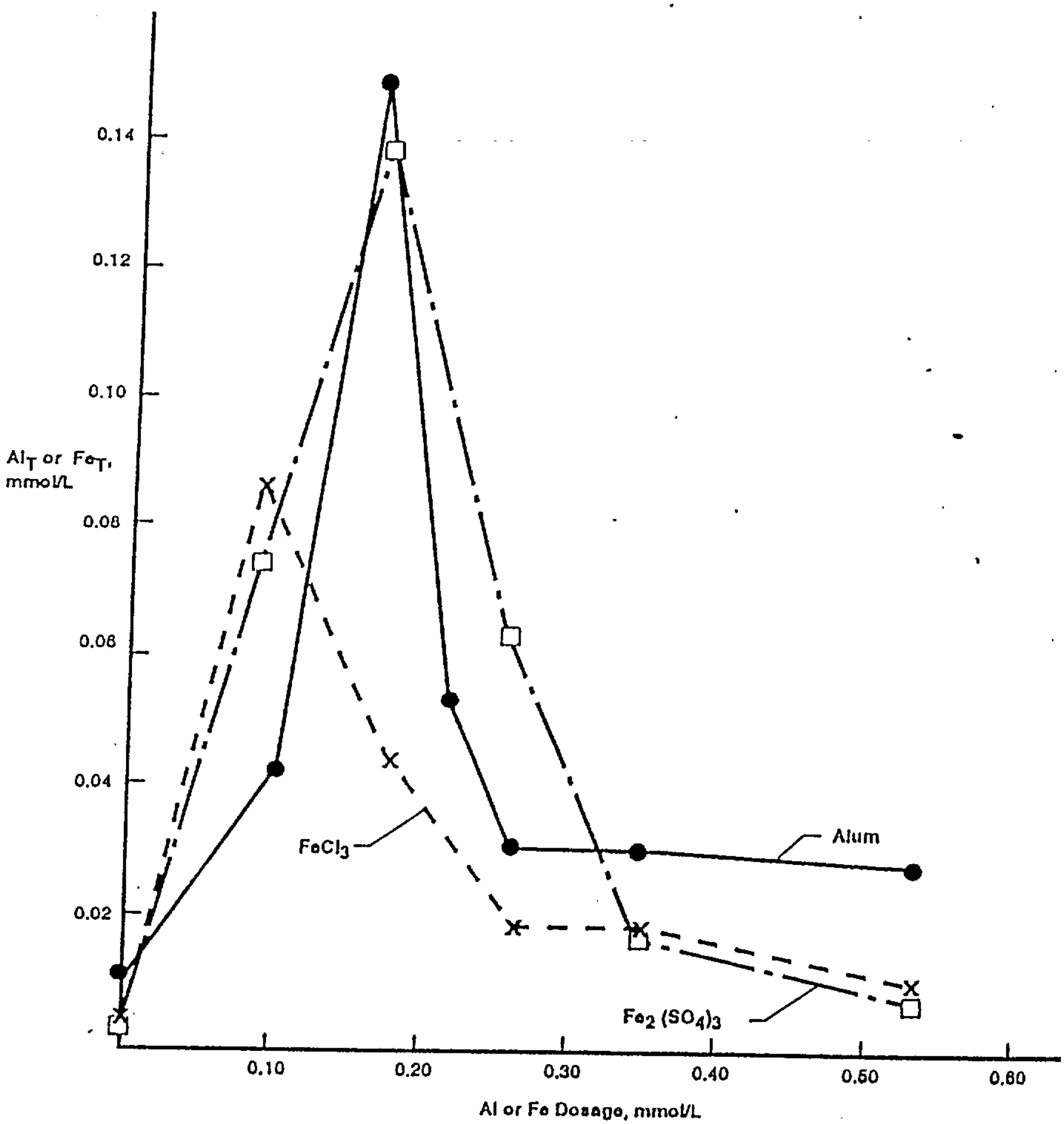


Figure 1-25. Al_T or Fe_T Residual vs. Al or Fe Dose, Sedimentation Experiments (Overflow Rate = 600 gpd/ft^2)

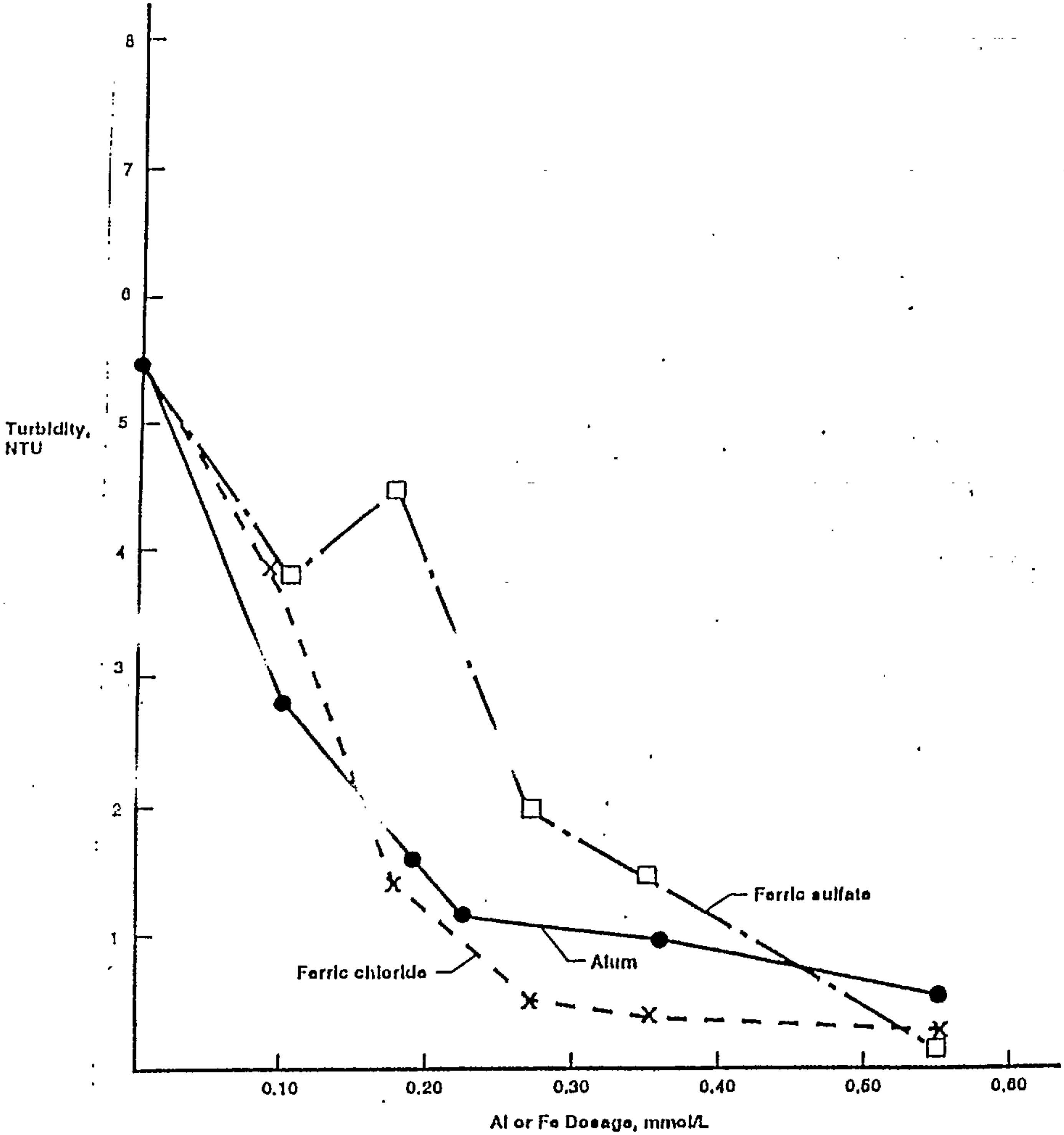


Figure 1-26. Turbidity vs. Al or Fe Dose, Filtration Experiments

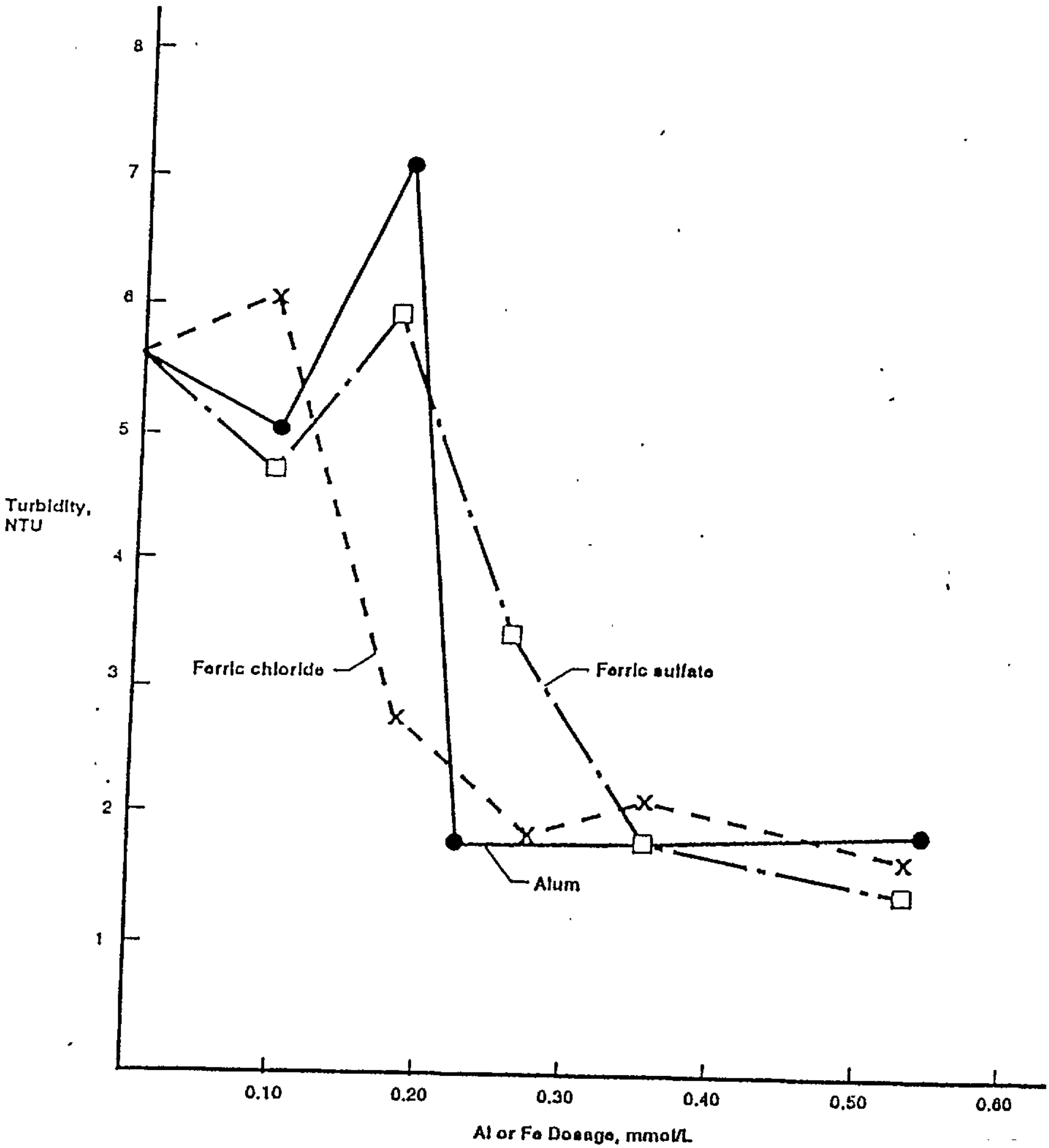


Figure 1-27. Turbidity vs. Al or Fe Dose, Sedimentation Experiments (Overflow Rate = 600 gpd/ft^2

Note that coagulant pollutant removal capacity is just one factor in the chemical selection. Other factors include cost, availability, purity, possible health and ecological effects, and treatment and disposal of process residues.

Comparison of Direct Filtration and Chemical Treatment /Sedimentation. For chemical doses of less than or equal to 0.2 mM (about 6 mg/l Al and 12 mg/l Fe) direct filtration has the distinct advantage in terms of minimum TP, turbidity, and coagulant residual (Figures 1-11 through 1-19). Once these dosages are exceeded, differences in effluent quality tend to be reduced, but sedimentation systems may become necessary because direct filtration systems are less capable of carrying the heavy chemical solids load.

Note that the solids load is heavier than conventional direct filtration systems typically carry, even at chemical doses of 0.2 mM and below. Any direct filtration systems installed in the Everglades must be capable of carrying heavy solids loadings. The Wahnbach Reservoir direct filtration system is designed for heavy loadings. The three-media Wahnbach system uses a top layer of very large-diameter activated carbon to provide the solids storage capacity it needs. Everglades designs must be along these lines.

Effect of Polymers-Part II. As described in Part I, the use of an anionic polymer was crucial to the experiments performed. It was not possible to get good or reproducible filtration results without it.

It was decided to also test a cationic polymer. Cationic polymers, like metallic coagulants, are positively charged and can reduce the negative charge on runoff water solids, leading to coagulation. Cationic polymers are also reported to produce less sludge than metallic coagulants (leading to reduced filter loadings), and to produce a sludge that is easier to dewater. However, polymers have no P-precipitation capabilities. The intent was to partially replace the metallic coagulant with polymer, anticipating that it might scavenge the coagulant demand offered by organic components of the treated waters, thus freeing up the metallic coagulant for P precipitation. The benefits of reduced sludge production were also anticipated.

American Cyanamid's Magnifloc 581C was tested as a partial replacement for alum. This polymer is a quaternary amine compound with a molecular weight of about 1×10^7 and a charge density of about 0.60 coulombs per milligram. The cationic polymer was allowed to react with the treated waters for 30 seconds before alum addition. Then the pH was adjusted, the mixture flocculated to build a floc, the anionic polymer added, then flocculation resumed. (This procedure was more fully described under Procedures, on page 1-4). It was observed that formation of small floc occurred during the initial flocculation period. This floc appeared weak, and the water stayed turbid. After the anionic polymer was added, the floc appeared to be exceptionally good, better than if no cationic polymer had been used. The cationically-produced floc appeared to act as seeds with which the metallic coagulant and anionic polymer could react more favorably.

Conditions for Figures 1-28, 1-29, and 1-30: pH = 7.0, anionic polymer = 0.5ug/L

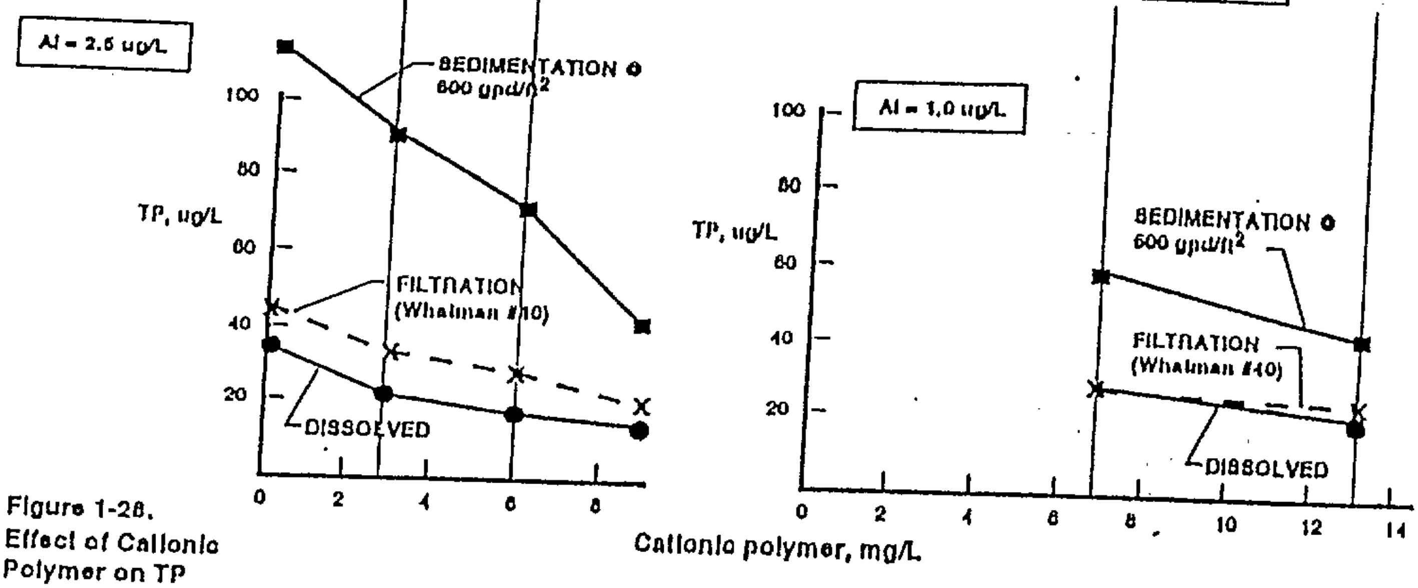


Figure 1-28.
Effect of Cationic Polymer on TP

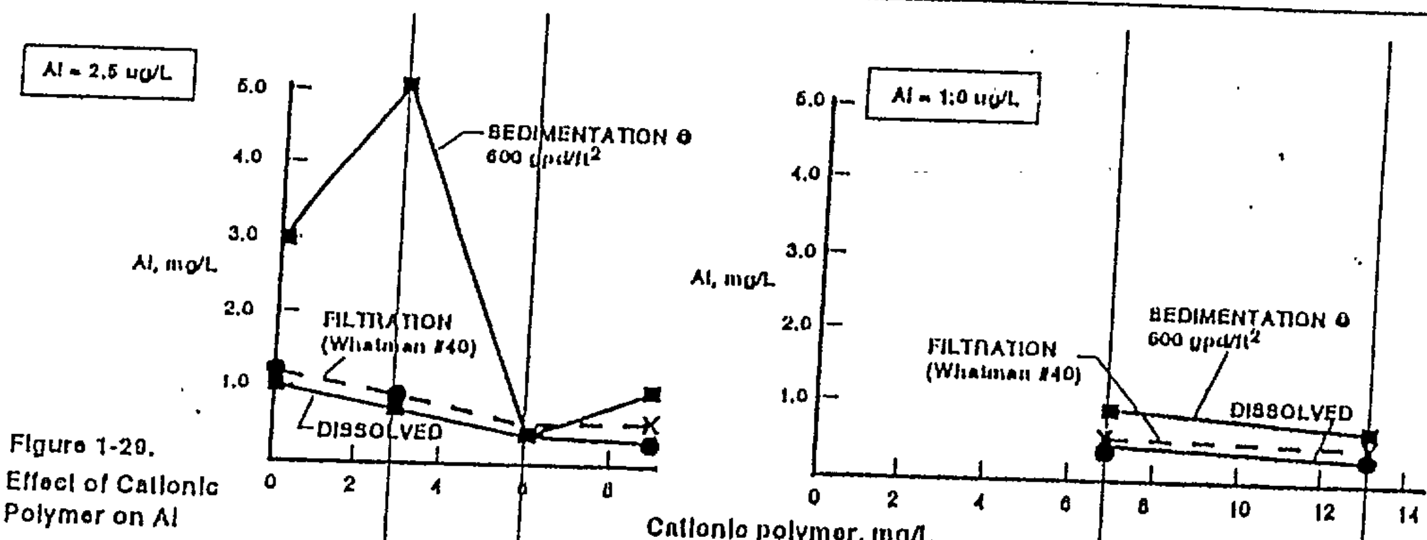


Figure 1-29.
Effect of Cationic Polymer on Al

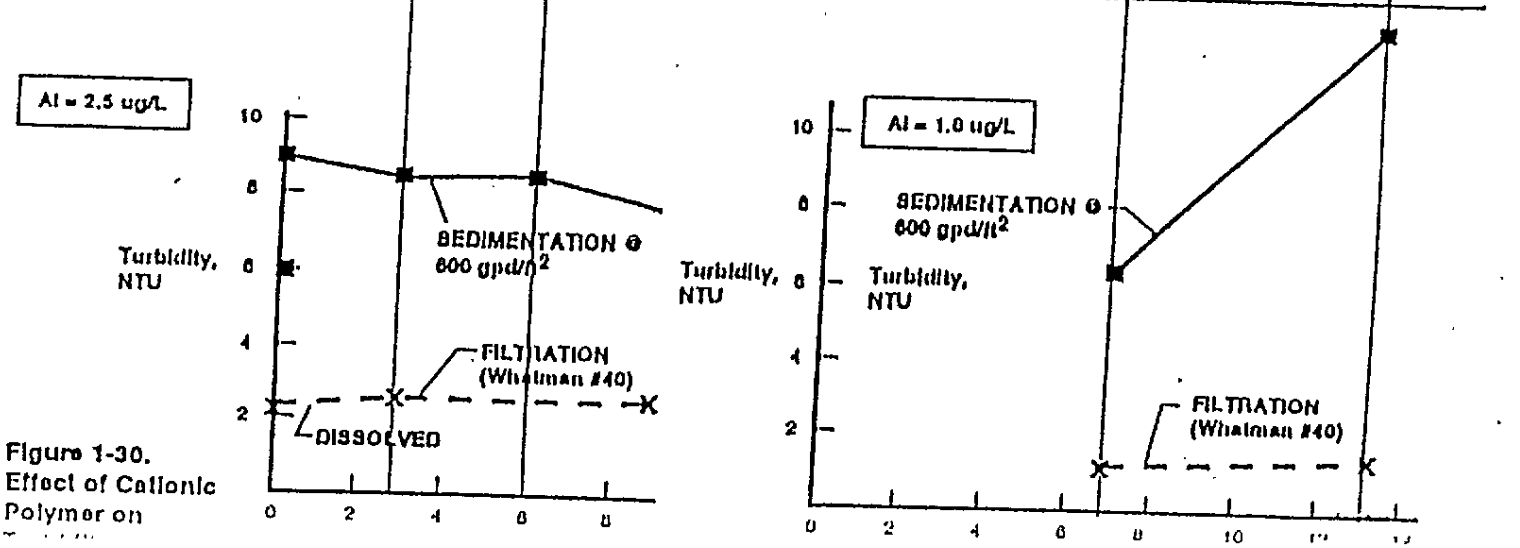


Figure 1-30.
Effect of Cationic Polymer on

Figures 1-28 through 1-30 show the effects of varying cationic polymer doses while operating at reduced aluminum doses (1.0 and 2.5 mg/l Al). The dissolved TP decreased somewhat with increasing polymer dose, indicating that the polymer was freeing up some aluminum to react with phosphorus (Figure 1-28). However, the improvements were not enough to offset the loss of P-precipitating capability caused by the reduction in alum dosage, since TP residuals were higher than they had been when the Al dosage was 5 to 6 mg/l.

Dissolved Al residuals also decreased as the polymer dose increased (Figure 1-29). Large improvements to particulate TP and Al removal were observed in the sedimentation experiments as the polymer concentration was increased. The improvements to particulate removal were only marginal for the filtration experiments. The polymer had almost no effect on turbidity removal (Figure 1-30).

Economic Impacts. Table 1-3 compares chemical costs, expected effluent quality, and sludge production for the alum and ferric chloride design conditions listed in Table 1-2 and used in Batch D experiments. Several observations are particularly notable:

1. Lime should be used as a pH adjustment chemical instead of sodium hydroxide. This replacement dramatically drops the chemical cost of alum treatment (compare Scenarios 1 and 2) and ferric chloride treatment (compare Scenarios 7 and 8).

2. Use of cationic polymer to replace a portion of the alum results in higher TP residuals and chemical costs, but substantially lower solids production (compare Scenarios 2 and 3).

3. Chemical costs are significantly higher than the chemical costs for direct filtration estimated in the Amendment 4 Report ($8 per million gallons). These higher costs are due mainly to higher primary coagulant demands observed in the bench tests.

4. Surface runoff water solids comprise a large portion of the solids production figure. Some of these solids could be settled out in a flow equalization basin located ahead of the plant. Removal of these solids would reduce filter loadings and perhaps reduce coagulant demand. Thus, the basin could provide added benefits above flow (and possibly concentration) equalization.

It is important to note that chemical doses, chemical costs, and sludge production depend on untreated water quality. Waters with higher TP concentrations may require more coagulant than needed in the bench-scale tests. Higher concentrations of coagulant-demanding substances (algae, for example) will have the same effect. Dr. Bernhardt and Mr. Schell[4] show how coagulant demand at Wahnbach Reservoir changes seasonally (Figure 1-35). The iron demand is only 2.5 mg/l in the winter, but it rises to 12.5 mg/l during summer plankton blooms. Pretreatment (microstraining or ozone) may be useful in reducing Everglades coagulant demands if algal blooms are anticipated in the waters receiving treatment.

Table 1-3 Operating Data

	Scenario 1	2	3	4	5	6	7	8
Coagulant	Alum	Alum	Alum	Alum	$FeCl_3$	$FeCl_3$	$FECl_3$	$FeCl_3$
Dosage, mg/L	6, as Al	6, as Al	2.5	6	10, as Fe	10, as Fe	20, as FE	20, as Fe
Dollars/mgal	35	35	15	35	15	15	15	15
Base								
Dosage, mg/L	18, as NaOH	9, as CaO	-	9, as CaO	36, as NaOH	18, as CaO	120, as NaOH	60, as CaO
Dollars/mgal	27	2	-	2	54	3.	180	23
Catonic polymer								
Dosage, mg/L	-	-	6	6	-	-	-	-
Dollars/mgal	-	-	48	48	-	-	-	-
Anionic polymer								
Dosage, mg/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Dollars/mgal	8	8	8	8	8	8	8	8
Total chemical cost, dollars/mgal	70	45	63		77	18	143	61
Expected effluent quality								
From filter								
P, µg/L	10	10	30	10	20	20	10	10
Coag. resid, mg/L	0.4, as Al	0.4, as Al	0.5, as Al	0.25	1.0, as Fe	1.0, as Fe	0.1, as Fe	0.1, as FE
From sedimentation								
P, µg/L	15	15	70	10	25	25	15	15
Coag. resid, mg/L	1.2, as Al	1.2, as Al	0.5	0.5	2.5, as Fe	2.5, as Fe	0.8, as Fe	0.8, as FE
ΔSO_4, mg/L	+32	+32	+13	+32	-	-	-	-
ΔNa, mg/L	+10	-	-		21	-	69	-
ΔCa, mg/L	-	+0.9	-	+0.9	-	2	-	12
ΔCl^-, mg/L	-	-	-	-	19	19	38	38
Solids production, mg/L								
Chemical solid	17.3, as $Al(OH)_3$	17.3, as $Al(OH)_3$	7.2	17.3, as $Al(OH)_3$	19, as $Fe(OH)_3$	19, as $Fe(OH)_3$	38, as $Fe(OH)_3$	38, as FE $(OH)_3$
Bound water	4.3	4.3	1.8	4.3	4.8	4.8	9.5	9.5
Cationic polymer	-	-	-	6	-	-	-	-
Anionic polymer	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Wastewater solids	20	20	20	20	20	20	20	20
Sum	42.1	42.1	29.5	48	44.3	44.3	68.0	68.0

[a]Estimated chemical costs:
1. Fe from $FeCl_3$ = \$0.18/lb
2. Fe from $Fe_2(SO_4)_3$ = \$0.45/lb
3. Al from $Al_2(SO_4)_3 \cdot 14\,H_2O$ = \$0.70/lb
4. Cationic polymer = \$0.95/lb
5. Anionic polymer = \$2.00/lb
6. NaOH = \$0.18/lb
7. CaO = \$0.023/lb

Treatment Results With Batches C and D

As indicated previously, all of the chemical optimization work was done with Batch A water, which was rather dilute. Therefore tests were also done with batches C and D, which had compositions more in line with compositions of waters historically received and to be expected in the future at Pump Station S-5A. Batch C was the most concentrated sample taken. Batch D was a fairly fresh sample (processed within a few hours after sampling). Batch D was processed to answer potential objections that the work with samples a few days old was not valid because aging had somehow changed their treatability. Alum and ferric chloride were the primary coagulants. Cationic polymer was employed in most tests.

Table 1-4 presents results of the Batch C and Batch D tests. Alum produced the lower TP residuals. The tests that used cationic polymer had dramatically lower coagulant residuals and turbidities than tests at the same condition that had not used polymer (contrast Table 1-4 results with results in Figures 1-12 and 1-13, 1-18 and 1-19). The improved results may have been due solely to the use of the cationic polymer. They might also have been caused in part by the different water composition and age.

Water Quality Effects. The untreated and treated waters from Batch D were analyzed for a wide spectrum of components to see how treatment changed their concentrations. These components might be critical to the health of plants and animals in the receiving water. Alum, cationic polymer, and anionic polymer doses were 6, 6, and 0.5 mg/l, respectively. The pH was controlled at 7.0. Table 1-5 presents the results.

The analyses suggest:

1. The predominant form of P in the treated effluent was organic P. Because of uncertainties associated with P analyses at the very low P concentrations being measured, it was not possible to discern whether the organic P was in the dissolved or particulate form. P residuals might be reduced if techniques to alter the organic-phosphorous bond were utilized, e.g., oxidation.

2. True color was significantly removed by treatment (86 percent). COD and TOC were moderately removed (46 and 42 percent, respectively). DOC was marginally removed (28 percent). BOD_5 was low in both the untreated and treated waters.

   The color removals (80 percent) were greater than the color reductions (50 percent) obtained in earlier experiments with alum. The TOC removals were not as great as the removals obtained in Dr. Bernhardt's and Mr. Schell's experiments with the simulated Everglades water in Germany (Figure 1-32).

   Unless the BOD_5 test failed, the water appears to be unbiodegradeable. Thus native TOC or DOC may not be a suitable reducing reagent for denitrification in

Table 1-4 Results of Tests With Different Water Samples

Experiment	Batch C 1	Batch C 2	Batch C 3	Batch C 4	Batch C 5	Batch C 6	Batch D 1	Batch D 2
Primary coagulant	Alum	Alum	Alum	Ferric sulfate	Ferric sulfate	Ferric sulfate	Alum	Ferric sulfate
Primary coagulant dose, mg/L	3.5 Al	5 Al	10 Al	7 Fe	10 Fe	20 Fe	6 Al	10
Cationic polymer, mg/L	6	6	0	6	6	0	6	6
Anionic polymer, mg/L	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
pH	7.0	7.0	7.0	7.5	7.5	7.5	7.0	7.5
P Results								
Untreated								
Total P, μg/L	147	147	147	147	147	147	120	120
Dissolved total P, μg/L	56	56	56	56	56	56	44	44
Treated								
Total P, μg/L								
Filtered (Whatman #40)	38	9	12	17	19	17	13	20
Settled (600 gpd/ft^2)	20	20	14	22	23	16	11	20
Dissolved total P, μg/L	13	11	16	16	16	14	<4	9
Coagulant residuals								
Untreated								
Total, mg/L	1.17 Al	1.17 Al	1.17 Al	0.62 Fe	0.62 Fe	0.62 Fe		
Dissolved, mg/L	-	-	-	-	-	-		
Treated								
Total, mg/L								
Filtered (Whatman #40)	0.31 Al	0.11 Al	0.55 Al	0.19 Fe	0.10 Fe	0.08 Fe	0.25 Al	0.19 Fe
Settled (600 gpd/ft^2)	0.64 Al	0.52 Al	0.52 Al	0.70 Fe	0.61 Fe	0.63 Fe	0.47 Al	0.60 Fe
Dissolved total, mg/L	0.18 Al	0.09 Al	0.34 Al	0.044 Fe	0.024 Fe	0.051 Fe	0.13 Al	0.03 Fe
Turbidity, NTU								
Untreated	17	17	17	17	17	17	12	12
Filtered (Whatman #40)	0.64	0.30	1.7	0.62	0.36	0.36	0.31	0.68
Settled (600 gpd/ft^2)	1.9	1.3	1.9	2.2	1.4	1.4	0.74	1.6

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QMS-PS825

Table 1-5 Analyses of Untreated and Treated Water, Batch D

Parameter	Batch D, untreated	Batch D, treated
Total P, µg/L	120	10
Total dissolved P, µg/L	44	<4
Total reactive P, µg/L	55	<4
Dissolved reactive P, µg/L	37	<4
Total acid hydrolyzable P, µg/L	39	<4
Dissolved acid hydrolyzable P, µg/L	5	<4
Total organic P, µg/L	26	6
Dissolved organic P, µg/L	<4	<4
TKN, mg/L	0.90	0.46
Dissolved TKN, mg/L	0.75	0.46
NH_4-N, mg/L	0.06	0.05
NO_3-N, mg/L	0.36	0.34
NO_2-N, mg/L	<0.02	<0.02
TOC, mg/L	27.9	16.2
DOC, mg/L	16.9	12.1
BOD_5, mg/L	1.0	<0.5
COD, mg/L	41	22
True color CPU/L	60	12
pH	7.6	7.0
Ca, mg/L	45	43
Mg, mg/L	13	12
Alkalinity, mg/L, as $CaCO_3$	102	84
SO_4, mg/L	27.5	63.5
Cl, mg/L	74	74
Na, mg/L	46	51
K, mg/L	5	5
TSS, mg/L	15	0.4
TDS, mg/L	408	400
Turbidity, NTU	12	-

Table 1-5 Analyses of Untreated and Treated Water, Batch D (continued)

Parameter	Batch D, untreated	Batch D, treated
Total SiO_2, mg/L	7.8	6.8
Dissolved SiO_2, mg/L	7.6	6.7
Total Al, mg/L	0.115	0.331
Dissolved Al, mg/L	<0.03	0.078
Total Fe, mg/L	0.23	0.015
Dissolved Fe, mg/L	0.095	<0.01
Total Mo, µg/L	<10	<10
Dissolved Mo, µg/L	-	-
Total Mn, µg/L	14	5
Dissolved Mn, µg/L	<5	5
Total W, µg/L	<50	<50
Dissolved W, µg/L	<50	<50
Total Se, µg/L	<5	<5
Dissolved Se, µg/L	<5	<5
Total Zn, µg/L	5	<5
Dissolved Zn, µg/L	45[a]	9[a]
Total Co, µg/L	<20	<20
Dissolved Co, µg/L	<20	<20
Total Cu, µg/L	<5	<5
Dissolved Cu, µg/L	<5	<5
Total Hg, µg/L	<2	<2
Dissolved Hg, µg/L	-	-
Heterotrophic plate count, CFU/L	17,700	2,350

[a]Contamination suspected. It is common for dissolved zinc to exceed total zinc when field filtration is involved.

Treated Water Conditions:

pH = 7.0
Alum = 6.0 mg/L Al
Cationic = 6.0 mg/L
Anionic = 0.5 mg/L
Settled overnight and decanted from sludge

the deep-bed filters.

3. Measured sulfate and sodium increases were moderate (36 and 5 mg/l, respectively) and correspond closely to increases calculated to be caused by the chemical reagents (alum and sodium hydroxide). The percentage increases in sulfate were 130 and 11 percent, respectively.

4. Alum treatment increased total and dissolved Al concentrations modestly, but reduced total and dissolved iron concentrations, and total manganese concentrations.

5. Treatment reduced silica concentrations slightly (13 percent). Dr. Jones was concerned that chemical treatment would eliminate substantial amounts of silica. It is our belief that it would take a lot more coagulant to make significant reductions.

6. The removals of other trace elements could not be estimated, because their concentrations were all below detection limits in both untreated and treated waters. The inductively-coupled plasma (ICP) method was used to analyze the samples. Detection limits are lower for graphite furnace atomic adsorption spectrophotometry (GFAAS) for some elements. These elements can be re-analyzed, at additional cost. The GFAAS detection limits are as follows:

   A. Co = 5 ug/l
   B. Cu = 5 ug/l
   C. Mo = 5 ug/l

Sludge Analyses. Sludges from each of two beakers of Batch D treated water were dried and weighed to calculate solids production. The calculated production from Beaker Number 1 was 46 mg/l and from Beaker Number 2 was 52 mg/l. A desk-top check of this calculation was made as follows:

1. Estimated $Al(OH)_3$ production = 2.9 x alum dose = 2.9 x 6 = 17.4 mg/l.

2. Bound water assumed to be 25 percent of $Al(OH)_3$ production = 0.25 x 17.4 = 4.3 mg/l.

3. Cationic polymer assumed to be completely adsorbed to sludge = 6 mg/l.

4. Anionic polymer assumed to be completely adsorbed to sludge = 0.5 mg/l.

5. Native solids captured = 15 - 0.4 = 14.6 mg/l.

Table 1-6 Estimate of Batch D Sludge Potential to be a Hazardous Waste

Parameter	Concentration		Maximum possible extract concentration, mg/L	Limiting extract concentration, mg/L
	mg/kg, wet solids	mg/kg, dry solids[a]		
As	<5	<68.6	<3.4	5
Ba	5.12	70.2	3.5	100
Cd	<0.5	<6.9	<0.35	1
Cr	12	164.6	8.2	5
Pb	<5	<68	3.4	5
Hg	<0.25	<3.4	<0.17	0.2
Ag	<0.5	<6.9	0.35	5.0
Se	<5	<68.6	<3.4	1.0

[a]Concentration, mg/kg dry solids estimated from concentration, mg/kg wet solids and sludge solids concentration (7.29 percent).

6. Sum of above = 42.8 mg/l. This value checks the production calculated for Beaker Number 1 rather well, Beaker Number 2 less well.

The sludge was then analyzed for metals that are listed in the TCLP. The concentrations of the metals that would occur in the TCLP extract if the metals were completely leached from the solids were then computed. These concentrations (in mg/l) are 20 times less than the sludge elemental analyses (expressed as milligrams metal per kilogram dry solids), because the weight of extractant used in the TCLP is 20 times the weight of dry solids. These maximum concentrations were then compared against TCLP metals limits for the extract. Table 1-6 shows the results. Only chromium and selenium had the potential to make the sludge a hazardous waste. The maximum potential extract concentration for chromium exceeded the TCLP limit. The maximum potential extract concentration for selenium may have exceeded the TCLP limit, but this is not certain because the measured selenium concentration was below detection limits. Whether chromium or selenium concentrations will exceed TCLP limits can only be determined under actual extraction conditions. Such evaluations are not possible at the current bench scale level and will have to wait for pilot testing, when enough sludge is generated to run the TCLP tests.

Sludge pollutant concentration is influenced not only by the concentration of pollutants in the untreated water and treated effluent, but by the purity of the treatment chemicals. Batch D sludge was generated from water treated with commercial-grade alum and sodium hydroxide, thus sludge metal concentrations were representative of concentrations that would be found in alum sludges from full-scale treatment facilities. Note that purity of commercially-available reagents varies by individual vendor. Reagent purity is one factor to consider in purchase of chemicals for full-scale treatment facilities.

Plant Flowsheet

Figure 1-34 is the flowsheet for the recommended direct filtration plant. The highly successful Wahnbach Reservoir direct filtration plant uses some of the features shown on Figure 1-34. Dr. Bernhardt describes this plant as a "floc filtration" plant, because it includes a flocculator. This differentiates this kind of plant from an "in-line" filtration plant, which has no flocculator. The effect of flocculation on direct filtration performance is a consequence of its shifting the particle-size distribution towards larger floc. Fundamental studies[6,7] have shown that particle removal efficiency is low for particles less than 5 microns in diameter and that the rate of headloss development is inversely proportional to particle size. By agglomerating small particles into larger ones, flocculation increases solids removal efficiency and increases run lengths.

The primary coagulant and pH-adjustment chemical are injected into the feedwater pump. Dr. Bernhardt has found that the intense turbulence in the pump provides the fastest and most effective means of distributing the chemicals uniformly throughout the water. The pH is automatically controlled. The destabilized solids flow to the flocculators in flow distribution channels. The delay between destabilization and flocculation does not adversely affect process

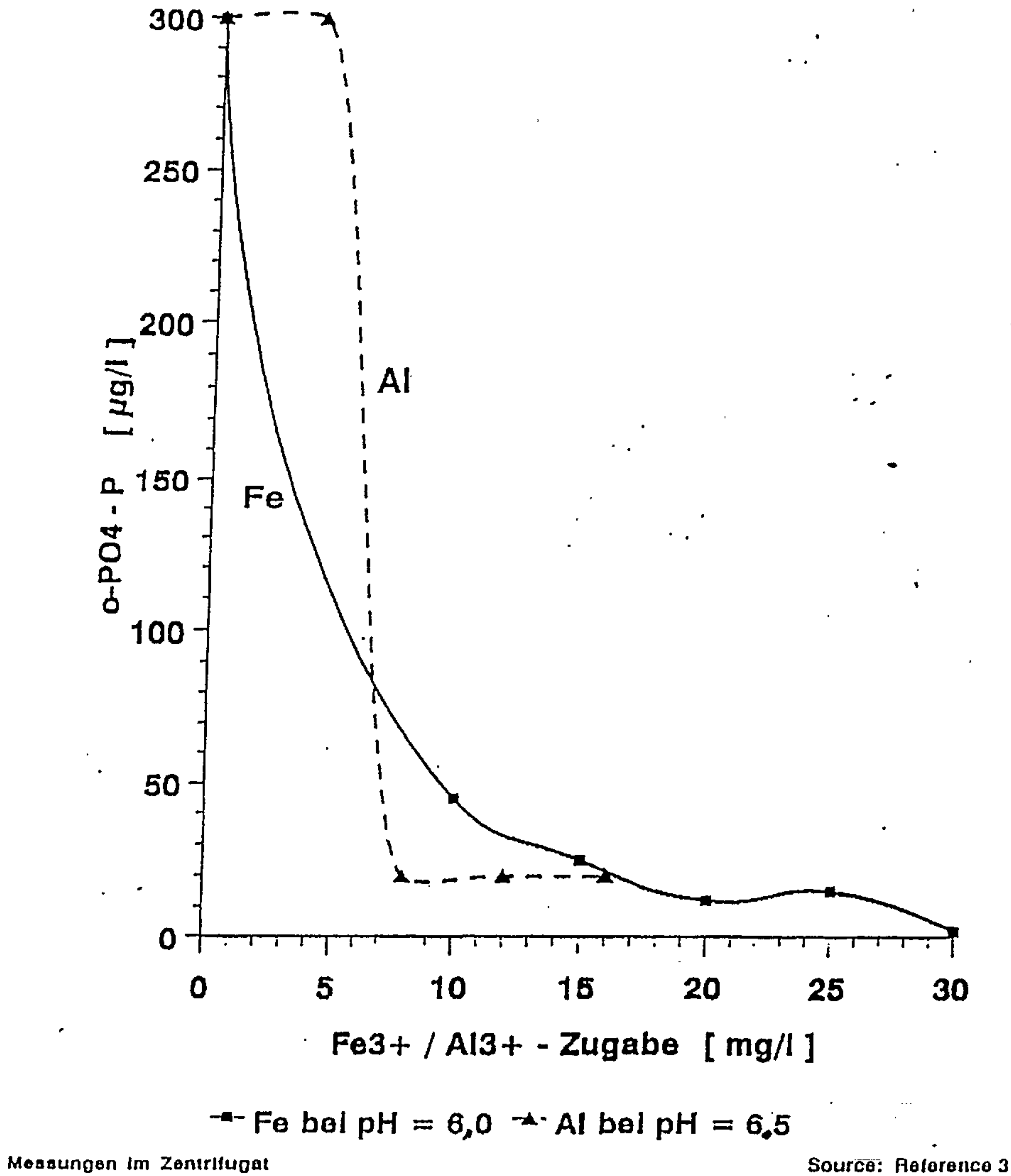


Figure 1-31. Flockung von Modellw. "Florida" mit 40 mg/l DOC als Huminsäure mit Fe-III-Chlorid bei pH = 6,0 und mit Al-III-Sulfat bei pH = 6,5

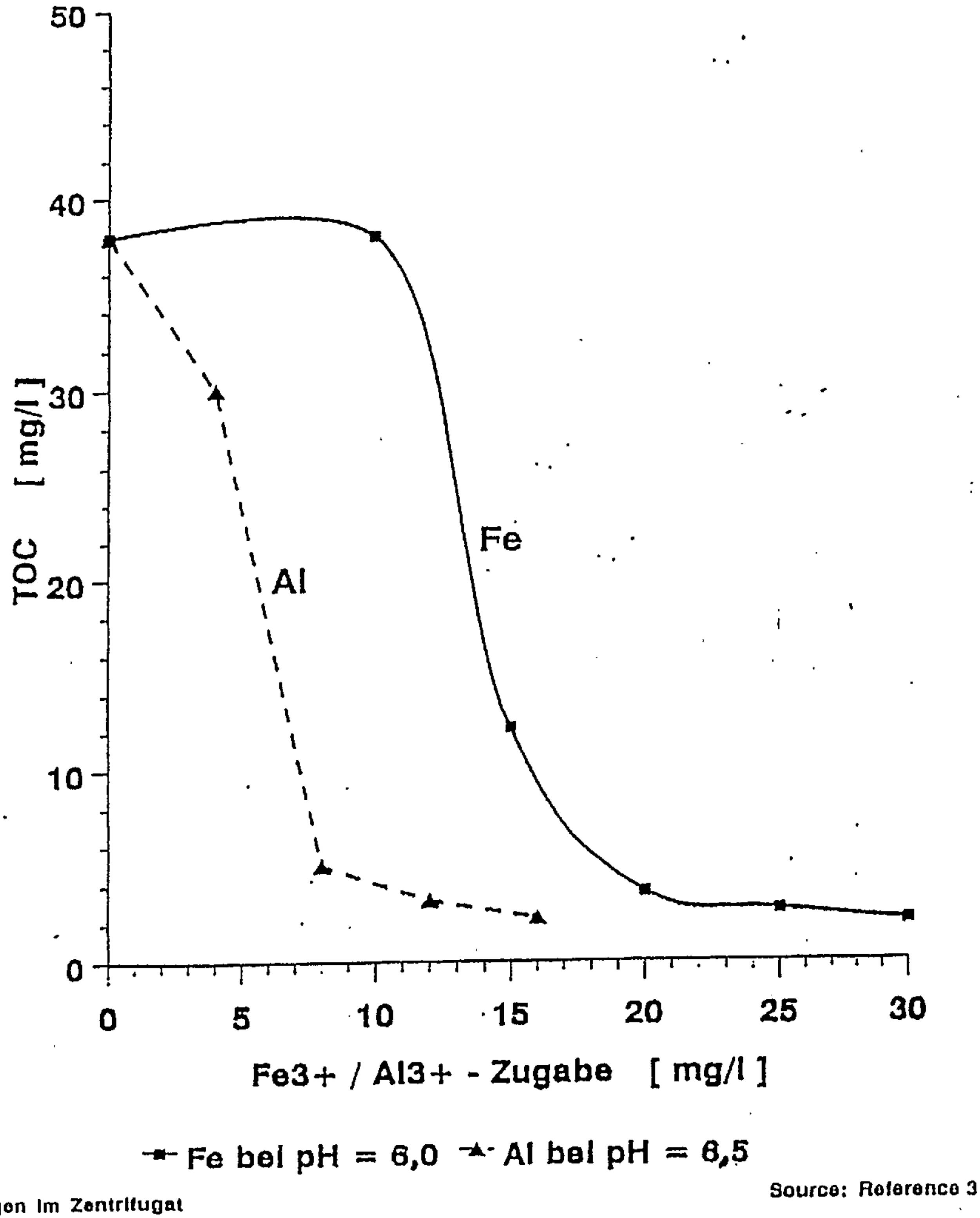
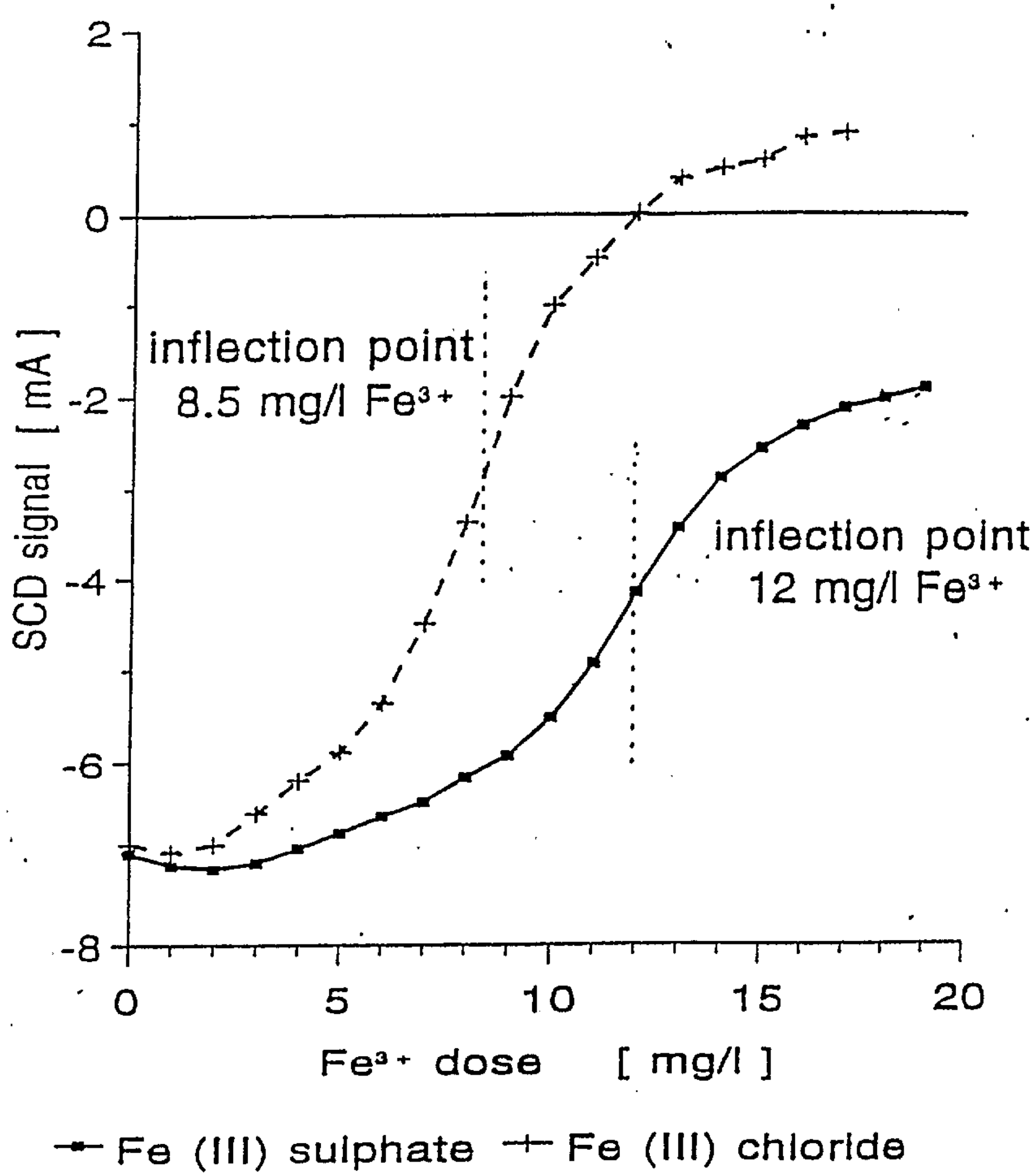


Figure 1-32. Flockung von Modellw. "Florida" mit 40 mg/l DOC als Huminsäure mit Fe-III-Chlorid bei pH = 6,0 und mit Al-III-Sulfat bei pH = 6,5



Source: Reference 4

Figure 1-33. Comparison of titration curves of pre-reservoir water (25 June 1991) with Fe^{3+} chloride and Fe^{3+} sulphate at pH 6.0.

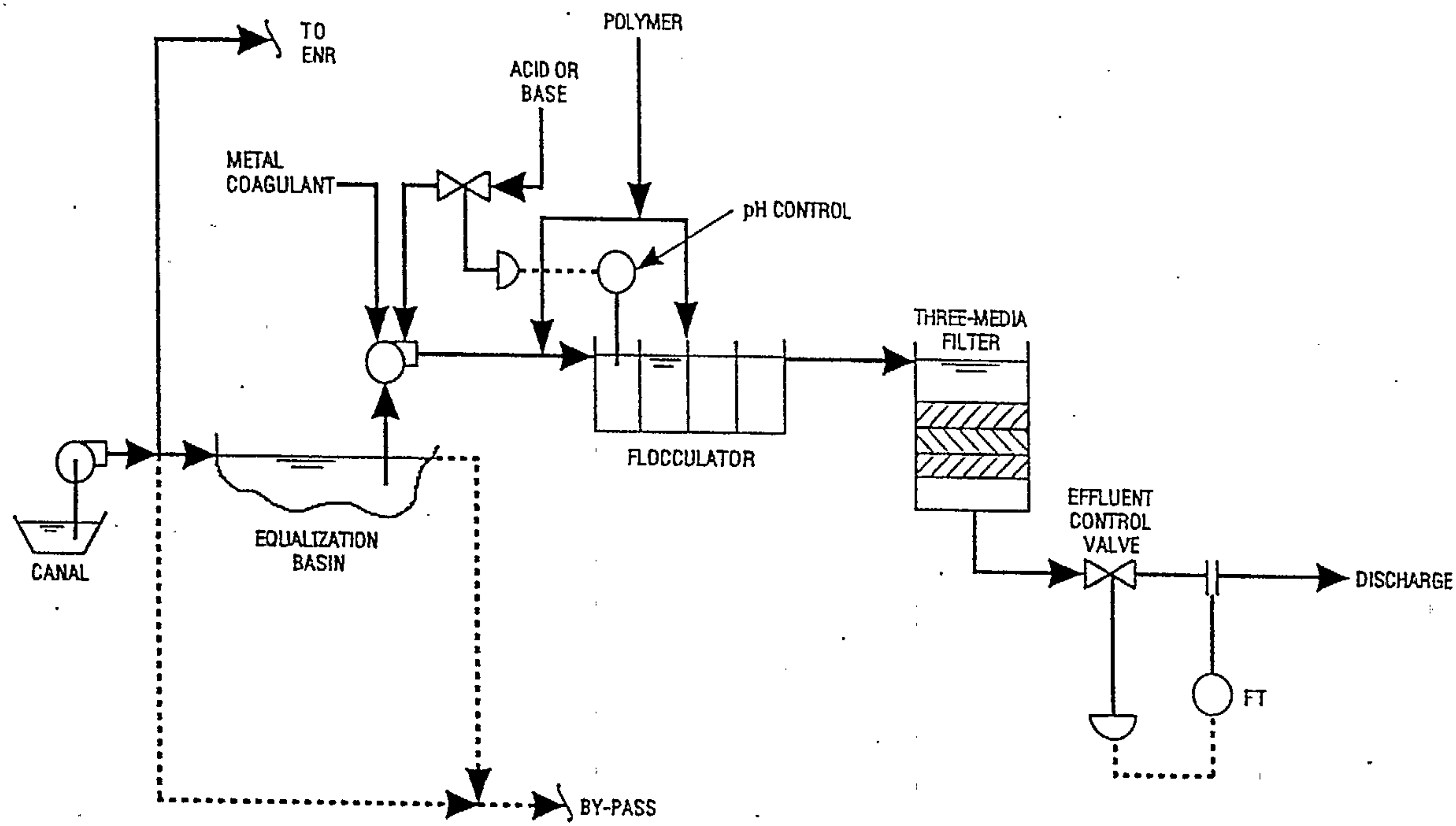


Figure 1-34. Recommended Flowsheet for Direct Filtration

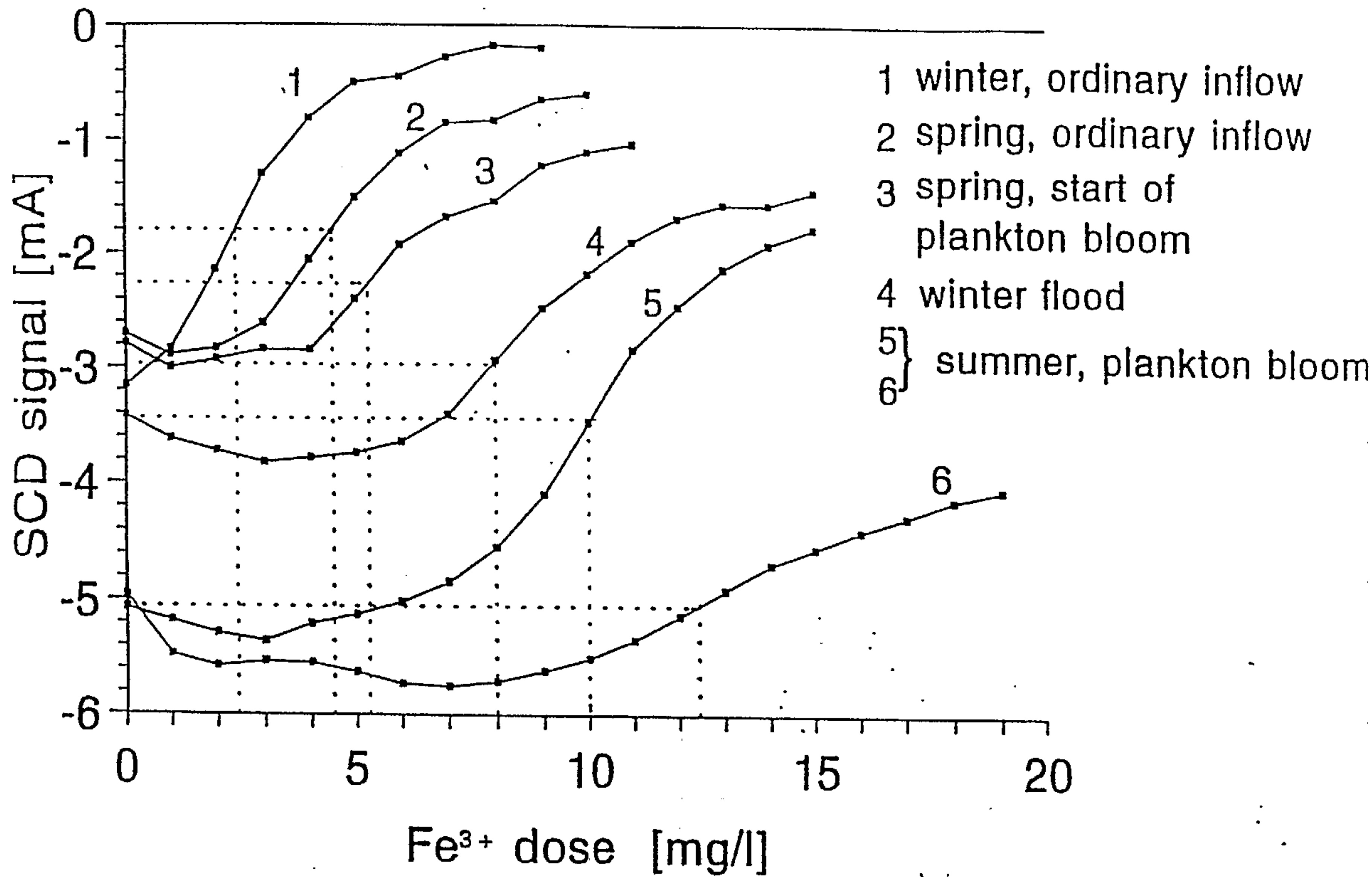


Figure 1-35.

Source: Reference 4

Seasonally fluctuating SCD titration curves **with** distinct shifts in the inflection points. Raw water pH-value adjusted to 6.

performance.

The flocculator provides about 15 minutes detention time at average flow. Several compartments are provided to minimize short circuiting. Anionic polymer is injected into the flocculator, either at the beginning of the flocculator or at its midpoint. The exact position will be determined by pilot testing. Fully-developed floc are produced for distribution onto the filters. Great pains are taken to maintain the integrity of the floc (i. e., to not break it up) once it has been formed. The flocculated water flows by gravity to the filters (it is not pumped). The filter feed is submerged so that there is no free-falling or splashing of the flocculated water onto the filter bed.

The filters are oriented as a three-media bed. The top media is a coarse, deep activated carbon that provides tremendous solids storage capacity. Dr. Bernhardt has indicated that filtration run times of 20 to 25 hours are possible with influent TSS concentrations of 50 mg/l, and that TSS concentrations of up to 80 mg/l can be handled, but run times drop to 10 hours at these higher loadings[5]. In recent conversations, Dr. Bernhardt has moderated somewhat on these predictions for run times. Filter bed solids storage capacity and run length times are critical parameters that must be defined a pilot study.

The Wahnbach Reservoir plant uses effluent valves to control flow. Dr. Bernhardt thinks he needs to be able to control filtering velocity at all times to prevent floc breakthrough. It is assumed that an Everglades direct filtration plant would use effluent flow control valves. It is possible that the strong floc produced with polymer conditioning may allow operation at high filtering velocities and allow omission of the effluent flow control valves. This would simplify maintenance and operations.

If cationic polymer is used, it is injected into the feedwater pump instead of the metal coagulant and the acid or base. After about 15 to 30 seconds of mixing in a pipeline or a small rapid mix tank, flow passes to a small rapid mix tank (nominal detention time 1-2 seconds) or to an in-line mixer where the metal coagulant and acid or base or added. The rest of the flowsheet is as described above.

The flowsheet for the sedimentation system is similar to Figure 1-34, except sedimentation tanks replace the filters.

Summary, Conclusions, and Recommendations

1. The optimum pH for alum treatment in the bench scale testing was about pH 7.0. The optimum pH for iron treatment was approximately pH 7.5. Phosphorus and coagulant residuals were both low in these pH ranges, and solids separations were effective.

2. Alum was the most effective primary coagulant for direct filtration because it could obtain low TP (7-12 ug/l) and low coagulant residuals (0.5 mg/l) at relatively low Al doses, in the neighborhood of 6 mg/l (0.22 mM). Also, alum

produces less chemical sludge than iron compounds at the same molar dosage. Iron compounds could not attain these low P residuals until higher doses were used (about 0.3 mM or 16 mg/l Fe). Whether these iron doses can be accommodated by direct filtration systems needs to be determined by pilot testing. If they cannot, then iron treatment would only be used with sedimentation systems.

3. If lower TP residuals are needed, or evidence about Al toxicity in water or sludges preclude the use of alum, then iron becomes the favored coagulant. However, relatively high iron doses (>0.3 mM) will be needed to attain low TP residuals, which may favor the use of sedimentation systems, which are typically not limited by solids loadings. Also, iron may be required if runoff waters are significantly more concentrated in TP or other coagulant-demanding substances (algae or dissolved organics, for example) than the runoff waters processed in this study. Pretreatment to reduce coagulant demand would be evaluated in the pilot study. Ferric chloride appears to be a better coagulant than ferric sulfate.

4. Direct filtration achieves low P and coagulant residuals at relatively modest reagent dosages. (Note that filtration is likely to produce somewhat better effluent quality at pilot and full scale than it did at bench scale). Sedimentation usually cannot achieve the same level of effluent quality, even when higher coagulant doses are used. However, sedimentation is simpler than direct filtration, and may be less costly overall. Both alternatives should be tested during the pilot-scale investigation.

5. The predominant form of P in highly-treated effluents appeared to be organic P. It was not determined whether the organic P is predominantly in dissolved or particulate form.

6. Use of an anionic polymer produced faster-forming, larger, stronger and discrete floc. These floc were vastly more amenable to filtration and sedimentation than floc generated when no anionic polymer was used. Use of anionic polymers should allow filtration or sedimentation processes to operate at higher rates with better treatment efficiency. Anionic polymers are relatively cost effective, because they are used in small amounts.

   Use of a cationic polymer (in conjunction with an anionic polymer) may have improved turbidity removals and reduced coagulant residuals. The cationic polymers should be further investigated to improve reduction of metals.

7. Chemical costs derived from bench-scale experiments are substantially greater than chemical costs reported in Amendment 4 calculations due to an increase in coagulant dosage over that assumed in the Amendment 4 work. Treatment costs are to be revised in Amendment 6 cost estimates. The calculations suggest that

lime should be used instead of sodium hydroxide for any upward pH adjustments, on a cost basis.

8. Flow equalization basins placed before the treatment plant will smooth out flow, thus making the plant smaller in total capacity and easier to operate. Flow equalization should also provide some limited concentration equalization. Equally important, flow equalization basins will reduce (to some currently unknown level) TSS and particulate P loadings on the treatment plant by sedimentation. This will in turn reduce chemical requirements and solids loadings on the treatment plant and improve the quality of any water that must be bypass the treatment plant. The effects of flow equalization facilities in possibly stimulating algal growth should be investigated further. Flow equalization should be investigated as part the pilot studies.

9. Alum treatment of Batch D water produced significant reductions in TP and color, moderate reductions in COD and TOC, and minor reductions in DOC and silica. Aluminum and sodium concentrations increased slightly. Iron and manganese concentrations were reduced slightly. Sulfate concentration increased moderately on a mass basis, but increased greatly on a percentage basis. Changes in trace element concentrations could not be measured as they were below the detection limits.

10. Desk-top sludge production estimates were confirmed by experimental work. For the level of this investigation, the use of the desk-top methods is reasonable to estimate sludge production at other treatment conditions.

11. Analysis of the sludge generated during alum treatment of Batch D water showed that only chromium, and possibly selenium, had the <u>potential</u> for exceeding the TCLP limits, thus making the sludge a hazardous waste. Whether these limits would actually be exceeded would have to be determined under pilot plant conditions.

    Sludge purity depends to some extent on the purity of treatment chemicals employed. Chemical purity varies with vendor. Chemical purity is one consideration in the purchase of chemicals for full-scale treatment facilities.

12. Other primary coagulants (for example: polymerized ferric sulfate, polyaluminum chloride) should be tested during the pilot study.

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3. Personal communication with Dr. H. Bernhardt.

4. Bernhardt, H. and Schell, H. "Control of Flocculants by Use of A Streaming Current Detector (SCD). In press.

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6. O'Melia, C. R. "Particles, Pretreatment, and Performance in Water Treatment". Journal of the Environmental Engineering Division, American Society of Civil Engineering, No. 6., 1985, page 874.

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TECHNICAL MEMORANDUM NO. 2 22-7518-01

May 5, 1993

TO: FILE

FROM: C. ZACHARY FULLER, P.E., SPENCER B. FORREST, RICHARD J. JUNNIER

SUBJECT: DAILY FLOW AND P LOAD DATA DEVELOPMENT, APPLICATION OF BMP, FE BASIN AND LAND AREA USAGE REDUCTION FACTORS

Daily Flow and P Load Data Development

A raw daily flow and load database was obtained from Burns and McDonnell (B&M) which contained several components of the total basin flow and P load. In each basin there are essentially two components to flow and P load: (1) those which originate from the Everglades Agricultural Area (EAA) and (2) those which are a result of regulatory releases from Lake Okeechobee. The distinction between these two components is pertinent because BMP adjustments to flows and loads are performed on only the EAA runoff component.

Basin S-5A Data Development

The components of Basin S-5A are defined as follows:

- S-5A RUNOFF: EAA runoff discharged to L-10/L-12.
- S-5A/HGS-5: Portion of any net diversion to WCA-1 at S-5A resulting from S-5A basin runoff.
- HGS-5: Discharge at HGS-5 to EAA.

Basin S-5A totals were determined from the sum of the following fields:

S-5A RUNOFF + S-5A/HGS-5 + (only negative values of) HGS-5.

Only negative values of HGS-5 (discharging to Lake Okeechobee) are used because lake contributions to the EAA are taken into account from S-5A/HGS-5 diversions. The HGS-5 discharges are subtracted from the EAA runoff (S-5A RUNOFF) because, on that day, the runoff discharges are leaving the basin and will not be contributing to the WCA.

BMP adjustments will eventually be made to only the S-5A RUNOFF component.

The gross flow/load total numbers are:

2,683,868 + 22,336 + (-27,540) = 2,678,664 acre-ft.
1,243,594 + 12,325 + (-7,842) = 1,248,077 lbs.

It is important to note that, for purposes of daily flows/loads for treatment plant modeling and analysis, only **positive, non-zero** daily flows and loads are permissible (i.e., meaningful) in the final totals. A negative sum of flows/loads can result from:

- Negative S-5A runoff flows/loads (i.e. withdrawals from L-10/L-12 canal) with no additional positive flows/loads from S-5A/HGS-5 or HGS-5 to offset the negative flows/loads.

- Discharge into Lake Okeechobee at HGS-5 which was greater than the runoff contributions from the EAA.

Therefore, the days where the final net sum of flows/loads is negative the flows/loads are "zeroed-out" and do not contribute to the final total flow/load. Adjusting the gross flow/load total by "zeroing out" net negative flow/load days, yields a total net flow/load out of the basin, over the period of record of 2,678,906 acre-ft and 1,587,621 lbs, respectively.

Basin S-6 Data Development

The components the Basin S-6 flow are defined as follows:

- S-6/RNOFF: Portion of any net diversion to WCA-1 at S-6 resulting from S-6 basin runoff.

- S-6/S-2: Portion of any net diversion to WCA-1 at S-6 resulting from Lake Okeechobee releases at S-2/S-351.

Basin S-6 totals were determined from the sum of the following fields:

S-6/RNOFF + S-6/S-2.

BMP adjustments will eventually be made to only the S-6/RNOFF component.
The total flow/load numbers are:

1,516,157 + 29,011 = 1,545,168 acre-ft.
6,477 + 634,936 = 641,413 lbs.

Basin S-7 Data Development

The components the Basin S-7/S-150 flow are defined as follows:

- S-7/RNOFF: Portion of any net diversion to WCA-2A at S-7 resulting from S-7 basin runoff.

- S-150/RNOFF: Portion of any net diversion to WCA-3A at S-150 resulting from S-7 basin runoff.

- Regulatory lake releases: Discharges from Lake Okeechobee that have been determined to flow into the WCAs.

Basin S-7/S-150 totals were determined from the sum of the following fields:

S-7/RNOFF + S-150/RNOFF + regulatory lake releases.

BMP adjustments will eventually be made to only the sum of S-7/RNOFF and S-150/RNOFF. On the appropriate days, regulatory lake releases are added.

Regulatory lake releases are applicable only to Basin S-7/S-150 and Basin S-8.

The net total flow/load numbers are:

1,952,406 + 231,346 + 82,431 = 2,226,183 acre-ft.
597,603 + 54,175 + 15,594 = 667,372 lbs.

Basin S-8 Data Development

The components of Basin S-8 are defined as follows:

- S-8/RNOFF: Portion of any net diversion to WCA-3A at S-8 resulting from S-8 basin runoff.

- S-8/G-88: Portion of any net diversion to WCA-3A at S-8 resulting from discharge to S-8 basin at G-88.

- S-8/G-136: Portion of any net diversion to WCA-3A at S-8 resulting from discharge to S-3 basin at G-136.

- Regulatory lake releases: Flows which were discharged from Lake Okeechobee that have been determined to flow into the WCAs.

Basin S-8 totals were determined from the sum of the following fields:

S-8/RNOFF + S-8/G-88 + S-8/G-136 + regulatory lake releases.

BMP adjustments will eventually be made to only the S-8/RNOFF component. The net total flow/load numbers are:

2,459,808 + 112,237 + 91,714 + 77,172 = 2,740,931 acre-ft.
1,450,916 + 113,232 + 15,287 + 15,053 = 1,594,488 lbs.

Total flows and loads are summarized in Tables 2-3 and 2-4, respectively.

Application of BMP Reduction Factors

Numerical analysis of on-farm best management practice (BMP) reductions for phosphorus (P) load and runoff flows were performed by Mock, Roos & Associates (MRA) as subconsultants to Brown and Caldwell (BC). Complete analysis and results of MRA's BMP modeling are contained in Appendix A-2 of this memorandum.

Data Set Interval

Based on the favorable correlation coefficient (Figure 3, Appendix A-2) and the historically seasonal nature of rainfall and flows within the EAA, it was decided that the four (4) month interval was an appropriate time period over which to apply individual BMP reduction factors. In other words, for each four month interval, one BMP flow and one BMP P load reduction percentage (for each basin) were determined by MRA's modeling of historical rainfall in the EAA. Four-month interval reduction factors were then applied on a daily basis to individual basin pumping and concentration data as provided to BC by Burns & McDonnell (B&M) via the District.

Small additional modifications were performed by BC in order to arrive at EAA-wide flow and P-load reductions of 20 and 25 percent, respectively. Table 6a in Appendix A-2 presents the four month BMP reduction factors as determined by MRA. MRA's analysis of rainfall data was performed from 2/80 through 9/88. For the time period 1/1/79 through 2/1/80 the overall BMP averages were applied. Table 2-1 and Table 2-2 include the additional modifications to the BMP reduction factors as calculated by MRA.

There are cases where the BMP reduction factors computed turn out to be negative. In these cases (February through May 1984, for example), application of the on-farm BMPs will actually result in a slight increase in flows and P loads during those months. These are referred to as "*negative reduction[s]*" by MRA (Appendix A-2, page 5). Over these time periods, BMP modifications were applied as slight increases to daily flow and P load.

Table 2-1 Four Month BMP Flow Reduction Factors

Dates	BMP Reduction Basin S-5A (percent)	BMP Reduction Basin S-6 (percent)	BMP Reduction Basin S-7 (percent)	BMP Reduction Basin S-8 (percent)
Jan-May '79	32.9	31.8	26.7	24.5
Jun-Aug	13.0	12.6	21.0	24.7
Sep-Jan '80	23.5	40.5	33.7	35.4
Feb-May	38.6	39.5	29.3	23.4
Jun-Sep	8.1	16.3	46.0	51.1
Oct-Jan '81	-2.7	81.9	67.3	81.9
Feb-May	81.9	81.9	61.5	81.9
Jun-Sep	14.2	11.9	9.6	43.1
Oct-Jan '82	50.7	-1.9	15.5	33.3
Feb-May	18.0	17.5	19.6	9.4
Jun-Sep	5.6	-0.2	6.0	1.9
Oct-Jan '83	20.8	40.9	0.9	40.3
Feb-May	21.6	24.0	16.8	20.6
Jun-Sep	15.2	17.2	19.3	30.1
Oct-Jan '84	10.0	28.6	13.2	-2.1
Feb-May	-0.1	-7.0	-0.8	9.4
Jun-Sep	24.7	21.9	34.0	14.3
Oct-Jan '85	40.6	81.9	68.6	30.0
Feb-May	60.4	17.4	30.9	30.6
Jun-Sep	3.7	3.3	10.2	21.4
Oct-Jan '86	37.3	51.5	66.1	21.7
Feb-May	32.9	30.3	21.5	-2.1
Jun-Sep	15.5	8.1	21.1	14.2
Oct-Jan '87	17.0	21.3	32.3	44.1
Feb-May	0.7	0.3	-0.9	13.8
Jun-Sep	17.7	25.9	33.7	24.6
Oct-Jan '88	14.0	20.0	5.8	33.9
Feb-May	42.3	81.9	62.2	33.8
Jun-Sep	12.0	8.7	9.2	21.5

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Table 2-2 Four Month BMP P Load Reduction Factors

Dates	BMP Reduction Basin S-5A (percent)	BMP Reduction Basin S-6 (percent)	BMP Reduction Basin S-7 (percent)	BMP Reduction Basin S-8 (percent)
Jan-May '79	36.2	35.1	30.0	27.8
Jun-Aug	16.3	15.9	24.3	28.0
Sep-Jan '80	26.8	43.8	37.0	38.7
Feb-May	41.9	42.8	32.6	26.7
Jun-Sep	11.4	19.6	49.3	54.4
Oct-Jan '81	0.6	85.2	70.6	85.2
Feb-May	85.2	85.2	64.8	85.2
Jun-Sep	17.5	15.2	12.9	46.4
Oct-Jan '82	54.0	1.4	18.8	36.6
Feb-May	21.3	20.8	22.9	12.7
Jun-Sep	8.9	3.1	9.3	5.2
Oct-Jan '83	24.1	44.2	4.2	43.6
Feb-May	24.9	27.3	20.1	23.9
Jun-Sep	18.5	20.5	22.6	33.4
Oct-Jan '84	13.3	31.9	16.5	1.2
Feb-May	3.2	-3.7	2.5	12.7
Jun-Sep	28.0	25.2	37.3	17.6
Oct-Jan '85	43.9	85.2	71.9	33.3
Feb-May	63.7	20.7	34.2	33.9
Jun-Sep	7.0	6.6	13.5	24.7
Oct-Jan '86	40.6	54.8	69.4	25.0
Feb-May	36.2	33.6	24.8	1.2
Jun-Sep	18.8	11.4	24.4	17.5
Oct-Jan '87	20.3	24.6	35.6	47.4
Feb-May	4.0	3.6	2.4	17.1
Jun-Sep	21.0	29.2	37.0	27.9
Oct-Jan '88	17.3	23.3	9.1	37.2
Feb-May	45.6	85.2	65.5	37.1
Jun-Sep	15.3	12.0	12.5	24.8

Flow Equalization Particulate Load Reduction

Because all flows are equalized in the flow equalization basin, a nominal reduction in particulate matter was assumed to take place during the equalization period (ranging from 1 to about 30 days). It was assumed for purposes of this analysis that a nominal 35 percent of the *particulate* matter (TSS) was removed from flow equalized waters, on average. TSS removal includes 35 percent of the particulate fraction of phosphorus in the runoff waters. The percent of particulate P fraction of total P was determined from the Oracle water quality data base as provided by the District.

Change in Land Use

EAA phosphorus discharges and P loads were reduced to reflect changes in land use resulting from conversion of land to use as flow equalization basins, treatment plant sites and solids handling facilities.

Table 2-3 and Table 2-4 present the unadjusted flow and P-load totals, the reduction factors as described above and the resulting adjusted flow and P-load totals.

Table 2-3 Reductions to Basin Flows
For the Period (Jan 1979 to Sept 1988)

Basin	Total Unadjusted Flows (acre-ft)	BMP Reduction[a]	Change in Land Use Reduction	Aggregate Reduction Factor	Total Adjusted Flows (acre-ft)
S-5A	2,678,906	0.819	0.978	0.801	2,145,755
S-6	1,545,168	0.809	0.986	0.798	1,233,044
S-7	2,266,183	0.790	0.988	0.780	1,768,801
S-8	2,740,931	0.758	0.979	0.742	2,033,996

Notes: [a] The four-month BMP reductions were applied daily and result in this overall reduction.

Table 2-4 Reductions to Basin P Loads For the Period (Jan '79 to Sept '88)

Basin	Total Unadjusted P Loads (lbs)	BMP Reduction[a]	FE Basin Reduction	Change in Land Use Reduction	Aggregate Reduction Factor	Total Adjusted P-Loads (lbs)
S-5A	1,587,621	0.788	0.857	0.978	0.660	1,048,558
S-6	641,413	0.769	0.860	0.986	0.652	418,253
S-7	667,372	0.750	0.810	0.988	0.600	400,891
S-8	1,594,488	0.703	0.720	0.979	0.496	790,118

Notes: [a] The four-month BMP reductions were applied daily and result in this overall reduction.

Daily flows and P loads adjusted for BMP reductions, flow equalization effects and changes in land use were used in the flow equalization basin/treatment plant sizing optimization program as explained in Technical Memorandum No. 3 of this report.

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APPENDIX A-2

ADDITIONAL WATER BUDGET MODELLING IN THE EAA

April, 1993

Mock, Roos & Associates, Inc.
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ADDITIONAL WATER BUDGET MODELLING IN THE EAA

APPENDIX

ADDITIONAL WATER BUDGET MODELLING IN THE EAA

PURPOSE

As a supplement to Appendix C of "Evaluation of On-Farm Best Management Practices", Amendment 3 (Draft Report, February 18, 1993), the water budget modelling effort was expanded to encompass the entire Everglades Agricultural Area (EAA). The objectives of this modelling effort are as follow:

1) To develop predicted farm runoff volumes (in inches per unit area) on a daily, monthly and yearly basis for each of the four major basins in the EAA (S-5A, S-6, S-7 and S-8 Basins).

2) To statistically compare the modelling data to estimated historical flows as calculated by Burns & McDonnell. The purpose of this statistical analysis is to estimate a reasonable interval (monthly, bi-monthly, tri-monthly, etc.) to apply modelled reductions to estimated historical data.

3) To predict the nine year average runoff volume reduction per basin that may occur as a result of implementing a pump Best Management Practice (BMP) and predict runoff volume reductions for various time intervals.

The purpose of this modelling is to provide engineers with reasonable predictions of the effects of implementing a pump BMP as a basis for designing stormwater treatment facilities. Information regarding the background of the Irrigation and Drainage Management Model (IDMM), the modifications to the model, and the pump BMP can be found in Appendix C of the above mentioned draft report.

EVALUATION

Thiessen Method

Considering the size of the EAA and the new emphasis placed on the modelling results, it was decided that a more scientific calculation of rainfall and pan evaporation was needed on a basin scale than previously performed. The Thiessen Method was employed to accomplish this task. The Thiessen Method is applied by simply constructing perpendicular bisects to lines that connect the monitoring station sites. The bisects are then extended until they intersect with other bisects to form an enclosed polygon around the monitoring station. This polygon represents the extent of the station's coverage.

Ten rainfall and four pan evaporation monitoring stations were chosen based on their vicinities and wholeness. Figures 1 and 2 illustrate the Thiessen Method as it was applied to rainfall and pan evaporation in the EAA. After the station coverage boundaries were established, a polygon overlay (or figure comparison) was performed by use of a computer Geographical Information System (GIS) which generated smaller polygons with a relational database that identified each polygon's station coverage, basin and area. For more flexibility in the analysis, the basins were subdivided based on their new and historic designations.

With the information in database form, the data was then manipulated to ultimately yield station coverage factors (or percentiles) per basin (see Tables 1 and 2). Annual monitoring station data and the results of applying the Thiessen Method are presented in Tables 3 and 4. Table 4 reflects a conversion from pan evaporation to evapotranspiration (ET) using conversion factors reported in a draft 1989 SFWMD report by Terry Ortel which references a procedure in "Crop Water Requirements", Paper 24 (1977) by the Food and Agriculture Organization (FAO).

Additional Model Modifications

There has been some interest in the irrigation data generated by the model. For this reason, it was decided that a modification was needed to the model regarding the irrigation delivery system efficiency. Previously, the model increased the daily calculated irrigation by a certain factor to account for evaporation losses from open water surfaces on the delivery canals and ditches. This is an acceptable means of accounting for such losses. However, it presented a problem when comparing pre-BMP and post-BMP model runs because of the inherent reductions of irrigation needs due to implementing the BMP. This reduction of irrigation needs intrinsically reduced the losses. A reduction in losses would not be expected. To maintain the same loss in both the pre- and post-BMP cases, the efficiency factor was removed and the crop data file was modified to included a year-round water surface area with a relatively high ET coefficient.

Additional modifications were made to improve the program interface. These modifications included the ability to read a data file and to display the yearly results at the end of each model run.

Calibration

Previously, calibration was performed on a yearly basis using the annual pump records of the Pahokee Water Control District. To test the model modifications and the new rainfall and ET data sets, a re-calibration was performed on Pahokee Water Control District to compare the results with the previous calibration. A slight change in the crop factor yielded an even closer calibration than before. Unfortunately, the pump records were not available on a monthly basis for a more in depth calibration.

A calibration was also attempted on Ritta Drainage District which was also a model calibration farm used by Hutcheon Engineers in the development of their model. However, there were too many conflicts found in the data to warrant continuation of the attempt. One notable contradiction was the fact that the pump records indicated less pumping on the wettest year than in dryer years.

Statistical Analysis

The Modified IDMM model was performed on the S-5A, S-6, S-7 and S-8 Basins and the results were compared to the estimated historical basin runoff volumes as calculated by Burns & McDonnell and presented in "Historical Discharge Data for the Everglades Agricultural Area", TM 3021-a1-002 (Draft, September 15, 1992). There has since been a final draft of this document issued. However, Burns & McDonnell have indicated that there have been no changes to the monthly runoff data.

There are several ways to statistically compare the two data sets. It was ultimately decided that a measure of the differences and overall correlations would be the best means of comparison. First, the monthly data sets for each basin were compiled into several smaller data sets that correspond to various monthly intervals ranging from one month with 104 data pairs (Jan 80 to Sep 88) to 104 months with one data pair. The absolute values of the differences between data pairs for each interval data set were averaged and divided by the average value of the estimated historical data to provide the average percent differences.

Perhaps the best way to see how two data sets compare is to calculate a correlation coefficient. Spearman's Rank Correlation Method was chosen which includes ranking each value in each set with a number ranging from one to the total number of data pairs. The sum of the squares of the differences in rankings is used to develop a correlation coefficient which can range from -1.0 to 1.0. A -1.0 indicates that an inverse relationship exists between the data sets and a value of 1.0 indicates a perfect direct correlation.

The results were graphed on a logarithmic scale (see Figure 3) to evaluate the performances and determine if there are any discernable trends. Each basin showed relatively high correlations at all intervals. S-8 Basin displayed the overall lowest correlation coefficient for reasons explained later in this report. As expected, the average percent of differences between the two data sets decreases as the intervals increase. All four basins exhibited high correlation coefficients between the three and six month intervals. The average percent difference appears to increase significantly at intervals below three months.

RESULTS

The results all showed a high correlation with the estimated historical runoff volumes, however, each basin exhibited a baseline percent difference. The overall nine year percent differences ranged from 3.8 percent in the S-5A Basin to 18.8 percent in the S-8 Basin. There are several factors that should be considered in comparing the data:

- The model results reflect farm runoff as if every farm in the basin were discharging at the same time in response to a rainfall event. The estimated historical runoff volumes represent an overall basin response which should respond slower.

- The basin areas are at such a scale that the Thiessen Method (or any similar method) may not always provide reliable rainfall or ET distributions. For instance, there is a lack of rainfall data available in the central portions of S-6, S-7 and S-8 Basins. These areas may have experienced a much different rainfall distribution at certain times. For example, despite the proximity of the CLEW and MIAMILO monitoring stations, a 20 inch difference in rainfall was reported in 1984.

- The estimated historical runoff volumes did not consider interbasin flows through the Bolles and Cross canals (L-21, L-16 and L-13) because of the lack of recorded flow at these locations. This could explain some of the baseline differences. For example, the model over-predicted runoff in the S-6 Basin by 9 percent and under-predicted the runoff in the S-5A and S-7 Basins by 4 percent and 7 percent, respectively. If the differences are due to interbasin flows, then the percentages of these differences would be expected to be larger at the smaller intervals.

- The S-8 Basin exhibited the largest baseline difference at 18.8 percent. The reason for which is believed to be the influence of the Holyland and Rotenburger tracts which have over 30 miles of frontage on SFWMD canals. It was confirmed that these tracts were not completely diked during the period of record and that there were even some direct connections. It is assumed that these tracts were contributing flow either in the form of direct discharge, sheetflow or seepage. because of the fact that the estimated historical runoff volumes for this basin were the largest in the EAA despite the fact that this basin experienced the least amount of rainfall. Since most of the runoff contribution from these unmanaged tracts has been to the SFWMD canals, it can not be incorporated into the model because the model is designed to estimate inflows and outflows to and from the farm tracts. The model considers farming practices when estimating flows and does not model flow from unmanaged land.

In regard to the percent volume reductions that may be experienced through the implementation of a pump BMP, it appears that there may be some inverse relation between rainfall and percent volume reduction. The annual results for each of the four basins are presented in Table 5. The results for the monthly, three month, four month and six month intervals are presented in Table 6a through 6d.

CONCLUSION

The intended users of this data should consider the above observations before choosing an appropriate interval and percent reduction. It is recommended that a worst case be considered in the design of any treatment facility. Worst cases appear to occur during the wetter periods. There are certain times when negative reductions (ie pump volume increases) occur as a result of implementing the BMP. These occurrences result from the fact that the water table is being held higher in the Post-BMP scenario than in the Pre. The higher water table reduces the farms' ability to store water during large storm events.

Examining the Pre- and Post-BMP pump output on the smallest possible interval, daily, shows that each day can be either 0% (if no Pre-BMP pumping occurred), 100% (if pumping occurred in the Pre-BMP but not in the Post) or a negative percent (if the BMP resulted in more pumping as described above). The nine year breakdown for the S-5A Basin is as follows:

0%	2677	Occurrences
100%	414	Occurrences
Negative%	79	Occurrences
Other%	21	Occurrences

These types of occurrences are present even at larger intervals. Negative reductions (increases) occur at intervals as large as four months. Since negative reductions are to be expected, it is recommended that the interval chosen include such occurrences.

A summary of the average predicted percent reductions for each basin is presented below along with the volume weighed reductions and the adjusted percent reductions:

	Nine Year Average Reduction	Volume Weighed Reduction	Adjusted Reduction
S-5A Basin	22.2%	21.8%	18.4%
S-6 Basin	20.6%	20.3%	17.2%
S-7 Basin	25.4%	24.7%	20.9%
S-8 Basin	30.6%	28.0%	23.7%

The nine-year average reduction simply reflects a summation of the annual percent reductions divided by nine. The results are presented here in this matter (and in Table 5) to be consistent with the way they were previously reported by engineers. A more accurate measure of the percent reduction is the volume weighed reduction which reflects the percent reduction between the nine-year summations of the pre- and post-BMP predicted runoff volumes.

The overall (volume weighted) predicted runoff volume reduction in the EAA is 23.7 percent. It has been suggested that to be consistent with previous assumptions and to be conservative, an overall volume reduction in the EAA of 20 percent should be considered while maintaining the relative differences between the basins. These adjusted reductions are reported above. Adjusted reductions have also been incorporated into Tables 6a through 6d on an interval basis.

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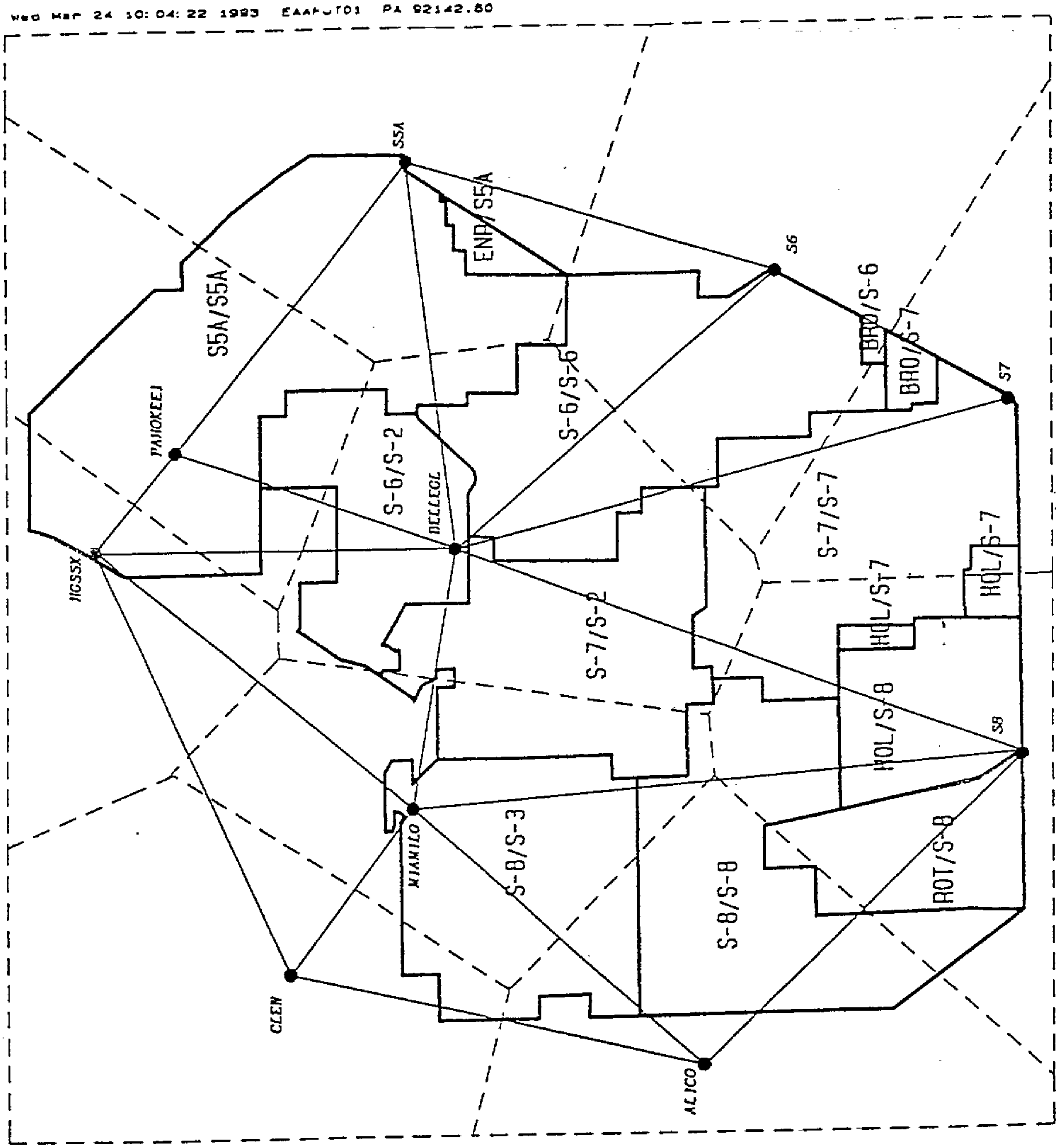

S-7/S-2 NEW/HISTORICAL BASIN DESIGNATION
BELLEGL MONITORING STATION
BASIN BOUNDARY
THIESSEN LINE
STATION COVERAGE BOUNDARY

N

SCALE 1:30000

THIESSEN METHOD APPLIED TO RAINFALL IN THE EAA

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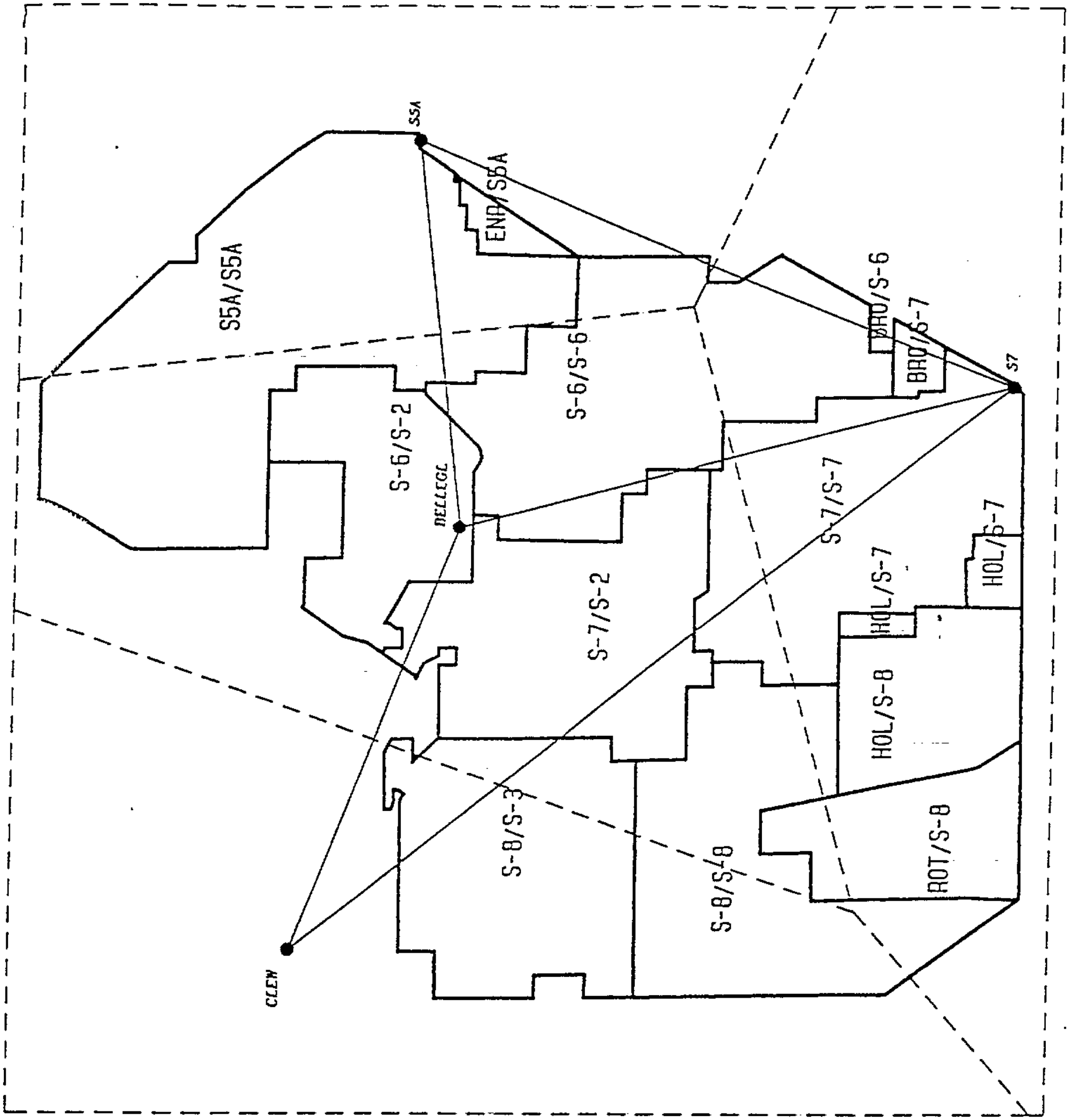

S-7/S-2 NEW/HISTORICAL BASIN DESIGNATION
BELLEGL MONITORING STATION
BASIN BOUNDARY
THIESSEN LINE
STATION COVERAGE BOUNDARY

N

SCALE 1:30000

THIESSEN METHOD APPLIED TO ET IN THE EAA

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Figure 2

TABLE 1: THIESSEN METHOD APPLIED TO RAINFALL

GIS FIGURE COMPARISON RESULTS

BASIN	STATION	ACRES
S5A/S5A	S5A	46123.2
S-7/S-7	S7	40893.8
S-8/S-8	MIAMILO	4679.8
S-7/S-2	MIAMILO	693.7
S-7/S-2	MIAMILO	17996.6
S-7/S-2	BELLEGL	46863.6
S-8/S-3	MIAMILO	45427.5
HOL/S-8	S8	29389.8
S-7/S-7	S8	17372.8
S-6/S-2	MIAMILO	25.4
S5A/S5A	HGS5X	13189.7
S5A/S5A	BELLEGL	7675.3
S5A/S5A	PAHOKEE1	55762.4
S-8/S-8	BELLEGL	131.8
S-6/S-6	S6	46512.4
S-6/S-6	S7	1421.8
S-6/S-6	BELLEGL	34353.9
ROT/S-8	S8	26196.5
ROT/S-8	ALICO	2634.5
S-8/S-3	ALICO	12402.6
S-7/S-2	S8	0.2
S-6/S-2	PAHOKEE1	7952.8
BRO/S-6	S7	170.5
S-7/S-7	S6	9196.7
BRO/S-7	S7	3370.8
HOL/S-7	S8	2505.7
S-8/S-8	S8	15792.8
S-8/S-8	ALICO	44568.7
S5A/S5A	S6	682.3
BRO/S-7	S6	32.1
S-6/S-2	BELLEGL	32381.9
ENR/S5A	S5A	4247.5
BRO/S6	S6	841.9
S-7/S-7	BELLEGL	7356.5
HOL/S-7	S8	1917.6
HOL/S-7	S7	1503.3
S-8/S-8	S8	5221.7
S-8/S-3	CLEW	5529.3
S-7/S-2	S6	141.3
S-8/S-8	BELLEGL	221.3

RAINFALL STATION COVERAGE PER BASIN IN ACRES

STATION	S5A	S-6	S-7	S-8
ALICO	0.0	0.0	0.0	56971.3
BELLEGL	7675.3	66735.8	54220.1	353.1
CLEW	0.0	0.0	0.0	5529.3
HGS5X	13189.7	0.0	0.0	0.0
MIAMILO	0.0	25.4	18690.3	50107.3
PAHOKEE1	55762.4	7952.8	0.0	0.0
S5A	50370.7	0.0	0.0	0.0
S6	682.3	46512.4	9338.0	0.0
S7	0.0	1421.8	40893.8	0.0
S8	0.0	0.0	17373.0	21014.5
TOTAL	127680.4	122648.2	140515.2	133975.5

RAINFALL STATION COVERAGE FACTORS PER BASIN

STATION	S5A	S-6	S-7	S-8
ALICO	0.000	0.000	0.000	0.425
BELLEGL	0.060	0.544	0.386	0.003
CLEW	0.000	0.000	0.000	0.041
HGS5X	0.103	0.000	0.000	0.000
MIAMILO	0.000	0.000	0.133	0.374
PAHOKEE1	0.437	0.065	0.000	0.000
S5A	0.395	0.000	0.000	0.000
S6	0.005	0.379	0.066	0.000
S7	0.000	0.012	0.291	0.000
S8	0.000	0.000	0.124	0.157

NOTE: The ENR basin was in sugarcane production during the period of record (1980-1988). Therefore, its area has been added to the S5A basin. The Holeyland, Rotenberger and Brown's Farm tracts are considered to have been ineffectively drained during the period of record. (Burns & McDonnell, TM 3021-A1-004, Draft: January, 1993)

TABLE 2: THIESSEN METHOD APPLIED TO EVAPOTRANSPIRATION

GIS FIGURE COMPARISON RESULTS

BASIN	STATION	ACRES
S-8/S-3	CLEW	50491.8
S-8/S-3	BELLEGL	12593.1
HOL/S-8	S7	29389.8
S-7/S-7	S7	62045.9
S-7/S-7	BELLEGL	12774.1
BRO/S-7	S7	3402.9
S-6/S-2	BELLEGL	40360.2
S5A/S5A	S5A	71338.4
S-8/S-8	BELLEGL	28002.1
S-6/S-6	S7	24864.8
S-6/S-6	BELLEGL	49622.2
ROT/S-8	S7	23565.3
S-8/S-3	BELLEGL	274.5
S-8/S-8	S7	7262.8
S-8/S-8	CLEW	31643.8
ROT/S-8	BELLEGL	5251.7
S5A/S5A	BELLEGL	52094.4
ENR/S5A	S5A	4247.5
S-6/S-6	S5A	7809.9
S-7/S-2	BELLEGL	65695.3
BRO/S-6	S7	1012.4
HOL/S-7	S7	4009.0
HOL/S-7	S7	1917.6
S-8/S-8	S7	3499.9

ET STATION COVERAGE PER BASIN IN ACRES

STATION	S5A	S-6	S-7	S-8
BELLEGL	52094.4	89982.4	78469.4	40869.7
CLEW	0.0	0.0	0.0	82135.6
S5A	75585.9	7809.9	0.0	0.0
S7	0.0	24864.8	62045.9	10762.7
TOTAL	127680.3	122657.1	140515.3	133768.0

ET STATION COVERAGE FACTORS PER BASIN

STATION	S5A	S-6	S-7	S-8
BELLEGL	0.408	0.734	0.558	0.306
CLEW	0.000	0.000	0.000	0.614
S5A	0.592	0.064	0.000	0.000
S7	0.000	0.203	0.442	0.080

NOTE: The ENR basin was in sugarcane production during the period of record (1980-1988). Therefore, its area has been added to the S5A basin. The Holeyland, Rotenberger and Brown's Farm tracts are considered to have been ineffectively drained during the period of record. (Burns & McDonnell, TM 3021-A1-004, Draft: January, 1993)

TABLE 3: ANNUAL RAINFALL

MONITORING STATION DATA (in inches)

Year	S5A	S6	S7	S8	ALICO	BELLEGL	MIAMILO	PAHOKEE1	CLEW	HGS5X
1980	48.14	42.73	37.57	48.13	34.12	46.18	38.93	47.94	41.23	42.30
1981	47.93	58.71	40.55	47.25	31.18	45.89	29.01	39.42	33.55	27.66
1982	53.79	62.29	54.25	54.18	56.80	68.48	46.48	54.56	56.20	41.18
1983	63.28	55.86	55.73	56.21	52.72	61.44	57.50	63.84	61.36	42.40
1984	46.38	43.02	31.92	32.73	38.87	43.81	40.93	45.75	60.84	37.49
1985	54.12	51.24	51.22	52.65	54.03	45.10	43.40	50.66	52.55	39.68
1986	58.77	66.44	51.99	53.73	48.49	48.97	49.48	47.18	50.40	46.23
1987	56.90	37.19	50.07	42.54	46.91	45.48	46.29	45.53	40.60	38.33
1988	45.41	40.99	38.21	39.08	40.23	37.46	36.04	47.87	40.93	47.81
Avg	52.75	50.94	45.72	47.39	44.82	49.20	43.12	49.19	48.63	40.34

THIESSEN METHOD PER BASIN (in inches)

Year	S5A	S6	S7	S8
1980	47.29	44.90	42.68	38.39
1981	42.00	50.27	43.12	32.97
1982	53.76	65.08	59.24	52.52
1983	61.15	59.46	58.17	55.44
1984	45.00	43.48	38.48	39.58
1985	50.55	47.93	48.03	49.76
1986	51.86	55.42	51.61	49.85
1987	49.20	42.33	45.99	45.64
1988	46.24	39.54	37.92	38.44
AVG	49.67	49.82	47.25	44.73

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TABLE 4: ANNUAL EVAPOTRANSPIRATION

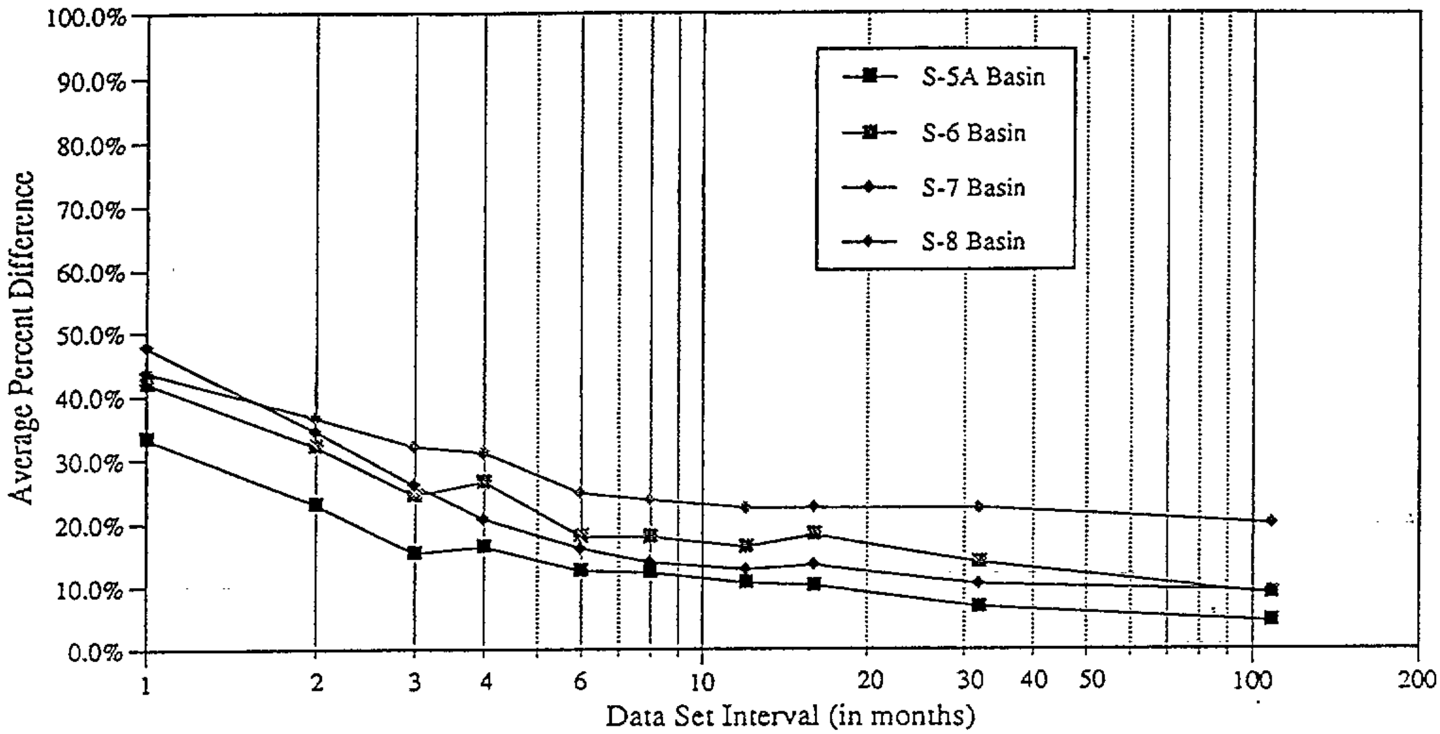
MONITORING STATION DATA (in inches)

Year	BELLEGL	CLEW	S5A	S7
1980	47.73	47.73	51.18	40.2
1981	50.55	50.54	53.7	45.23
1982	48.15	48.17	43.73	39.61
1983	51.41	46.42	43.84	42.3
1984	54.81	50.1	45.48	42.88
1985	53.09	48.62	47.83	55.85
1986	50.25	48.44	47.33	57.75
1987	50.05	51.9	49.03	59.91
1988	47.67	47.71	45.85	53.94
Avg	50.41	48.85	47.55	48.63

THIESSEN METHOD PER BASIN (in inches)

Year	S5A	S6	S7	S8
1980	49.77	46.43	44.41	47.13
1981	52.42	49.67	48.2	50.11
1982	45.54	46.14	44.38	47.47
1983	46.93	49.08	47.39	47.61
1984	49.28	51.79	49.54	50.96
1985	49.98	53.31	54.3	50.57
1986	48.52	51.58	53.56	49.74
1987	49.45	51.98	54.4	51.98
1988	46.6	48.83	50.44	48.2
Avg	48.72	49.87	49.62	49.31

COMPARISON OF ESTIMATED HISTORICAL RUNOFF TO MODIFIED IDMM PREDICTED RUNOFF



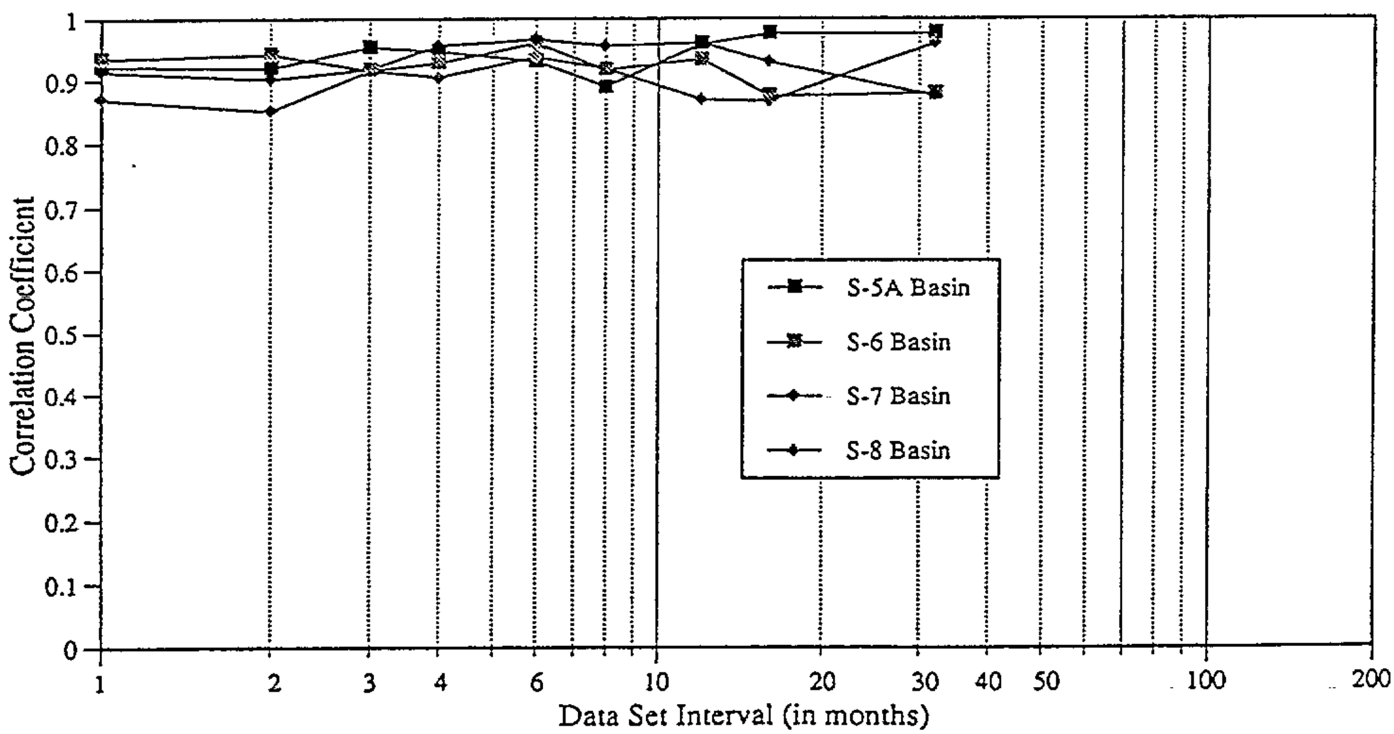


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Figure 3

TABLE 5: MODIFIED IDMM ANNUAL RESULTS

S-5A BASIN

Year	Rainfall (in)	Estimated Historical In (in)	Estimated Historical Out (in)	Model Pre-BMP Irr (in)	Model Pre-BMP Pump (in)	Model Post-BMP Irr (in)	Model Post-BMP Pump (in)		Percent Reduction
1980	47.29	9.36	23.71	6.06	21.75	1.32	16.48		24.2%
1981	42.00	11.08	14.29	15.60	15.32	11.44	11.24		26.6%
1982	53.76	10.63	34.83	6.58	27.65	4.44	21.27		23.1%
1983	61.15	9.52	38.12	4.16	37.67	0.00	31.07		17.5%
1984	45.00	13.68	25.86	8.40	23.84	2.24	19.31		19.0%
1985	50.55	11.31	25.41	8.49	21.59	4.10	17.45		19.2%
1986	51.86	7.57	24.30	5.70	24.61	2.44	18.00		26.9%
1987	49.20	8.78	24.27	9.59	24.89	5.19	21.36		14.2%
1988	46.24	3.91	20.62	4.09	24.79	0.43	17.59		29.0%
Total	447.05	85.84	231.41	68.67	222.11	31.60	173.77	Avg	22.2%

S-6 BASIN

Year	Rainfall (in)	Estimated Historical In (in)	Estimated Historical Out (in)	Model Pre-BMP Irr (in)	Model Pre-BMP Pump (in)	Model Post-BMP Irr (in)	Model Post-BMP Pump (in)		Percent Reduction
1980	44.90	5.04	15.56	5.58	15.98	1.09	10.66		33.3%
1981	50.27	8.96	16.36	12.18	21.86	7.11	18.03		17.5%
1982	65.08	2.46	29.40	5.73	35.14	1.92	30.22		14.0%
1983	59.46	3.22	22.89	7.24	28.85	1.80	20.64		28.5%
1984	43.48	9.07	15.94	10.81	16.28	5.88	14.65		10.0%
1985	47.93	9.91	16.41	11.55	16.72	9.60	14.66		12.3%
1986	55.42	4.11	26.20	6.52	22.02	2.99	16.98		22.9%
1987	42.33	8.62	13.18	12.23	14.40	7.69	10.95		24.0%
1988	39.54	6.24	12.25	4.29	12.14	2.55	9.38		22.7%
Total	448.41	57.63	168.19	76.13	183.39	40.63	146.17	Avg	20.6%

TABLE 5: MODIFIED IDMM ANNUAL RESULTS *(Continued)*

S-7 BASIN

Year	Rainfall (in)	Estimated Historical In (in)	Estimated Historical Out (in)	Model Pre-BMP Irr (in)	Model Pre-BMP Pump (in)	Model Post-BMP Irr (in)	Model Post-BMP Pump (in)		Percent Reduction
1980	42.68	4.18	17.76	5.96	19.01	1.18	10.94		42.5%
1981	43.12	9.53	17.98	14.27	19.27	7.73	14.57		24.4%
1982	59.24	2.62	35.53	6.43	33.82	2.66	27.73		18.0%
1983	58.17	3.50	32.58	5.64	31.83	2.38	25.66		19.4%
1984	38.48	9.66	23.59	9.53	15.45	4.55	11.65		24.6%
1985	48.03	10.60	20.86	10.00	17.23	7.46	13.93		19.2%
1986	51.61	4.99	25.82	9.08	21.39	4.26	13.99		34.6%
1987	45.99	8.06	16.06	10.06	17.39	6.00	13.71		21.2%
1988	37.92	6.47	15.46	7.27	14.51	3.97	10.84		25.3%
Total	425.24	59.61	205.64	78.24	189.90	40.19	143.02	Avg	25.4%

S-8 BASIN

Year	Rainfall (in)	Estimated Historical In (in)	Estimated Historical Out (in)	Model Pre-BMP Irr (in)	Model Pre-BMP Pump (in)	Model Post-BMP Irr (in)	Model Post-BMP Pump (in)		Percent Reduction
1980	38.39	10.60	20.89	6.17	16.91	0.49	10.15		40.0%
1981	32.97	11.83	13.76	15.00	11.50	7.66	4.71		59.0%
1982	52.52	6.60	41.38	6.54	28.11	4.27	25.44		9.5%
1983	55.44	5.73	35.87	4.72	32.87	0.85	24.16		26.5%
1984	39.58	14.28	18.12	7.19	17.77	1.93	14.24		19.9%
1985	49.76	6.84	26.34	5.11	20.18	1.85	13.70		32.1%
1986	49.85	6.59	40.96	7.77	25.35	2.86	19.55		22.9%
1987	45.64	8.11	24.12	8.24	21.77	2.61	14.41		33.8%
1988	38.44	9.87	15.78	5.86	18.08	0.48	12.27		32.1%
Total	402.59	80.45	237.22	66.60	192.54	23.00	138.63	Avg	30.6%

TABLE 6a: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-5A BASIN

Mon	Year	One Month Interval Pre-BMP (in)	One Month Interval Post-BMP (in)	Three Month Interval Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Four Month Interval Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Six Month Interval Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction
Feb	80	2.32	0	1	4.44	1.5	66.2%	56.0%	1	6.6	3.38	48.8%	41.3%					
Mar	80	0.7	0															
Apr	80	1.42	1.5															
May	80	2.16	1.88	2	6.46	3.63	43.8%	37.0%						1	13.38	11.67	12.8%	10.8%
Jun	80	1	0						2	11.22	9.79	12.7%	10.8%					
Jul	80	3.3	1.75															
Aug	80	0.1	0	3	6.92	8.04	-16.2%	-13.7%										
Sep	80	6.82	8.04															
Oct	80	0	0						3	0	0	0.0%	0.0%					
Nov	80	0	0	4	0	0	0.0%	0.0%						2	0.38	0	100.0%	84.6%
Dec	80	0	0															
Jan	81	0	0															
Feb	81	0.38	0	1	0.38	0	100.0%	84.6%	1	0.77	0	100.0%	84.6%					
Mar	81	0	0															
Apr	81	0	0															
May	81	0.39	0	2	1.71	0.63	63.2%	53.4%						1	13.99	10.89	22.2%	18.7%
Jun	81	1.11	0.63						2	13.6	10.89	19.9%	16.9%					
Jul	81	0.21	0															
Aug	81	9.18	8.13	3	12.28	10.26	16.4%	13.9%										
Sep	81	3.1	2.13															
Oct	81	0	0						3	0.95	0.35	63.2%	53.4%					
Nov	81	0.95	0.35	4	0.95	0.35	63.2%	53.4%						2	3.76	2.24	40.4%	34.2%
Dec	81	0	0															
Jan	82	0	0															
Feb	82	0.3	0	1	2.81	1.89	32.7%	27.7%	1	7.8	5.89	24.5%	20.7%					
Mar	82	2.51	1.89															
Apr	82	0	0															
May	82	4.99	4	2	14.09	9.75	30.8%	26.0%						1	24.44	19.38	20.7%	17.5%
Jun	82	6.7	5.75						2	17.05	15.38	9.8%	8.3%					
Jul	82	2.4	0															
Aug	82	2.85	4.5	3	10.35	9.63	7.0%	5.9%										

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TABLE 6a: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-5A BASIN *(continued)*

		One Month Interval		Three Month Interval					Four Month Interval					Six Month Interval				
Mon	Year	Pre-BMP (in)	Post-BMP (in)	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction
Sep	82	5.1	5.13															
Oct	82	2.4	0						3	6.23	4.5	27.8%	23.5%					
Nov	82	0.27	0	4	3.83	4.5	-17.5%	-14.8%						2	13.89	12	13.6%	11.5%
Dec	82	0.13	0															
Jan	83	3.43	4.5															
Feb	83	7.48	7.5	1	10.06	7.5	25.4%	21.5%	1	11.4	8.13	28.7%	24.3%					
Mar	83	2.4	0															
Apr	83	0.18	0															
May	83	1.34	0.63	2	6.83	4.94	27.7%	23.4%						1	21.16	19.07	9.9%	8.4%
Jun	83	4.93	4.31						2	15.78	12.44	21.2%	17.9%					
Jul	83	0.56	0															
Aug	83	3.51	1.5	3	14.33	14.13	1.4%	1.2%										
Sep	83	6.78	6.63															
Oct	83	4.04	6						3	7.06	6	15.0%	12.7%					
Nov	83	0	0	4	3.02	0	100.0%	84.6%						2	8.57	6	30.0%	25.4%
Dec	83	3.02	0															
Jan	84	0	0															
Feb	84	1.78	1.5	1	5.55	6	-8.1%	-6.9%	1	12.51	12.13	3.0%	2.6%					
Mar	84	2.65	4.5															
Apr	84	1.12	0															
May	84	6.96	6.13	2	10.82	8.43	22.1%	18.7%						1	15.73	12.06	23.3%	19.7%
Jun	84	2.14	0.8						2	8.77	5.93	32.4%	27.4%					
Jul	84	1.72	1.5															
Aug	84	0	0	3	4.91	3.63	26.1%	22.0%										
Sep	84	4.91	3.63															
Oct	84	0	0						3	2.56	1.25	51.2%	43.3%					
Nov	84	2.37	1.25	4	2.56	1.25	51.2%	43.3%						2	5.04	1.88	62.7%	53.0%
Dec	84	0.19	0															
Jan	85	0	0															
Feb	85	0	0	1	2.48	0.63	74.6%	63.1%	1	2.48	0.63	74.6%	63.1%					
Mar	85	0.89	0															

TABLE 6a: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-5A BASIN *(continued)*

Mon	Year	One Month Interval Pre-BMP (in)	One Month Interval Post-BMP (in)	Three Month Interval Period	Three Month Pre-BMP (in)	Three Month Post-BMP (in)	Three Month Percent Reduction	Three Month Adjusted Reduction	Four Month Interval Period	Four Month Pre-BMP (in)	Four Month Post-BMP (in)	Four Month Percent Reduction	Four Month Adjusted Reduction	Six Month Interval Period	Six Month Pre-BMP (in)	Six Month Post-BMP (in)	Six Month Percent Reduction	Six Month Adjusted Reduction
Apr	85	1.59	0.63															
May	85	0	0	2	5.58	4.57	18.1%	15.3%										
Jun	85	2.95	1.57											1	18.44	16.82	8.8%	7.4%
Jul	85	2.63	3						2	14.69	13.57	7.6%	6.4%					
Aug	85	2.57	0	3	12.86	12.25	4.7%	4.0%										
Sep	85	6.54	9															
Oct	85	3.75	3.25															
Nov	85	0	0	4	2.42	0	100.0%	84.6%	3	6.17	3.25	47.3%	40.0%					
Dec	85	0.67	0											2	5.01	1.5	70.1%	59.2%
Jan	86	1.75	0															
Feb	86	0.54	0	1	2.59	1.5	42.1%	35.6%										
Mar	86	2.05	1.5						1	2.59	1.5	42.1%	35.6%					
Apr	86	0	0															
May	86	0	0	2	10.49	6.87	34.5%	29.2%										
Jun	86	8.21	5.37											1	15.98	13.5	15.5%	13.1%
Jul	86	2.28	1.5						2	14.49	11.37	21.5%	18.2%					
Aug	86	2.57	4.5	3	5.49	6.63	-20.8%	-17.6%										
Sep	86	1.43	0															
Oct	86	1.49	2.13															
Nov	86	0.83	0	4	5.2	3	42.3%	35.8%	3	6.69	5.13	23.3%	19.7%					
Dec	86	3.46	3											2	9.48	7.5	20.9%	17.7%
Jan	87	0.91	0															
Feb	87	0.32	0	1	4.28	4.5	-5.1%	-4.3%										
Mar	87	3.96	4.5						1	4.69	4.5	4.1%	3.4%					
Apr	87	0	0															
May	87	0.41	0	2	5.25	3.67	30.1%	25.5%										
Jun	87	1.66	1.01											1	9.97	7.3	26.8%	22.6%
Jul	87	3.18	2.66						2	4.84	3.67	24.2%	20.4%					
Aug	87	0	0	3	4.72	3.63	23.1%	19.5%										
Sep	87	0	0															
Oct	87	4.72	3.63						3	16.43	13.19	19.7%	16.7%					

TABLE 6a: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-5A BASIN *(continued)*

		One Month Interval		Three Month Interval					Four Month Interval					Six Month Interval				
Mon	Year	Pre-BMP (in)	Post-BMP (in)	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction
Nov	87	9.73	9.56	4	11.71	9.56	18.4%	15.5%						2	14.88	11.06	25.7%	21.7%
Dec	87	0	0															
Jan	88	1.98	0															
Feb	88	1.57	0	1	3.17	1.5	52.7%	44.6%	1	3.21	1.5	53.3%	45.0%					
Mar	88	1.1	1.5															
Apr	88	0.5	0															
May	88	0.04	0	2	10.98	9.46	13.8%	11.7%						1	20.24	16.69	17.5%	14.8%
Jun	88	2.51	1.5						2	20.2	16.69	17.4%	14.7%					
Jul	88	8.43	7.96															
Aug	88	8.66	6.63	3	9.26	7.23	21.9%	18.5%										
Sep	88	0.6	0.6															

Period

1 = FEB ---> APR (DRY)
2 = MAY ---> JUL (WET)
3 = AUG ---> OCT (WET)
4 = NOV ---> JAN (DRY)

Period

1 = FEB ---> MAY (MOSTLY DRY)
2 = JUN ---> SEP (WET)
3 = OCT ---> JAN (MOSTLY DRY)

Period

1 = MAY ---> OCT (WET)
2 = NOV ---> APR (DRY)

TABLE 6b: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-6 BASIN

Mon	Year	One Month Interval Pre-BMP (in)	One Month Interval Post-BMP (in)	Three Month Interval Period	Three Month Interval Pre-BMP (in)	Three Month Interval Post-BMP (in)	Three Month Interval Percent Reduction	Three Month Interval Adjusted Reduction	Four Month Interval Period	Four Month Interval Pre-BMP (in)	Four Month Interval Post-BMP (in)	Four Month Interval Percent Reduction	Four Month Interval Adjusted Reduction	Six Month Interval Period	Six Month Interval Pre-BMP (in)	Six Month Interval Post-BMP (in)	Six Month Interval Percent Reduction	Six Month Interval Adjusted Reduction
Feb	80	1.17	0	1	3.2	2.15	32.8%	27.7%	1	5.55	2.78	49.9%	42.2%					
Mar	80	0.99	2.07															
Apr	80	1.04	0.08															
May	80	2.35	0.63	2	4.14	0.63	84.8%	71.7%						1	8.18	5.13	37.3%	31.5%
Jun	80	0	0						2	5.8	4.5	22.4%	19.0%					
Jul	80	1.79	0															
Aug	80	0.13	0	3	4.04	4.5	-11.4%	-9.6%										
Sep	80	3.88	4.5															
Oct	80	0.03	0						3	0.65	0	100.0%	84.6%					
Nov	80	0.62	0	4	0.62	0	100.0%	84.6%						2	0.9	0	100.0%	84.6%
Dec	80	0	0															
Jan	81	0	0															
Feb	81	0.28	0	1	0.28	0	100.0%	84.6%	1	0.66	0	100.0%	84.6%					
Mar	81	0	0															
Apr	81	0	0															
May	81	0.38	0	2	2.84	0	100.0%	84.6%						1	18.52	15	19.0%	16.1%
Jun	81	0	0						2	18.14	15	17.3%	14.6%					
Jul	81	2.46	0															
Aug	81	13.78	13.5	3	15.68	15	4.3%	3.7%										
Sep	81	1.9	1.5															
Oct	81	0	0						3	3.06	3.03	1.0%	0.8%					
Nov	81	3.06	3.03	4	3.06	3.03	1.0%	0.8%						2	8.24	6.57	20.3%	17.1%
Dec	81	0	0															
Jan	82	0	0															
Feb	82	1.43	0.63	1	5.18	3.54	31.7%	26.8%	1	12.43	9.46	23.9%	20.2%					
Mar	82	3.16	2.75															
Apr	82	0.59	0.16															
May	82	7.25	5.92	2	17.97	14.05	21.8%	18.4%						1	29.96	26.68	10.9%	9.3%
Jun	82	8.44	8.13						2	21.38	20.76	2.9%	2.5%					
Jul	82	2.28	0															
Aug	82	3.92	4.5	3	11.99	12.63	-5.3%	-4.5%										

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TABLE 6b: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-6 BASIN *(continued)*

Mon	Year	One Month Interval Pre-BMP (in)	One Month Interval Post-BMP (in)	Three Month Interval Period	Three Month Interval Pre-BMP (in)	Three Month Interval Post-BMP (in)	Three Month Interval Percent Reduction	Three Month Interval Adjusted Reduction	Four Month Interval Period	Four Month Interval Pre-BMP (in)	Four Month Interval Post-BMP (in)	Four Month Interval Percent Reduction	Four Month Interval Adjusted Reduction	Six Month Interval Period	Six Month Interval Pre-BMP (in)	Six Month Interval Post-BMP (in)	Six Month Interval Percent Reduction	Six Month Interval Adjusted Reduction
Sep	82	6.74	8.13															
Oct	82	1.33	0						3	3.88	1.88	51.5%	43.6%					
Nov	82	0	0	4	2.55	1.88	26.3%	22.2%						2	11.13	7.88	29.2%	24.7%
Dec	82	0	0															
Jan	83	2.55	1.88															
Feb	83	6.71	4.5	1	8.58	6	30.1%	25.4%	1	8.77	6	31.6%	26.7%					
Mar	83	1.83	1.5															
Apr	83	0.04	0															
May	83	0.19	0	2	5.58	4.76	14.7%	12.4%						1	15.52	12.76	17.8%	15.0%
Jun	83	4.32	3.26						2	12.77	9.76	23.6%	19.9%					
Jul	83	1.07	1.5															
Aug	83	4.14	2	3	9.94	8	19.5%	16.5%										
Sep	83	3.24	3															
Oct	83	2.56	3						3	4.76	3	37.0%	31.3%					
Nov	83	0	0	4	2.2	0	100.0%	84.6%						2	6.13	5.07	17.3%	14.6%
Dec	83	2.2	0															
Jan	84	0	0															
Feb	84	0	0	1	3.93	5.07	-29.0%	-24.5%	1	10.49	11.02	-5.1%	-4.3%					
Mar	84	1.78	3															
Apr	84	2.15	2.07															
May	84	6.56	5.95	2	8.72	5.95	31.8%	26.9%						1	11.68	9.58	18.0%	15.2%
Jun	84	0.69	0						2	5.12	3.63	29.1%	24.6%					
Jul	84	1.47	0															
Aug	84	0.14	0	3	2.96	3.63	-22.6%	-19.1%										
Sep	84	2.82	3.63															
Oct	84	0	0						3	0.67	0	100.0%	84.6%					
Nov	84	0.67	0	4	0.67	0	100.0%	84.6%						2	3.19	1.92	39.8%	33.7%
Dec	84	0	0															
Jan	85	0	0															
Feb	85	0	0	1	2.52	1.92	23.8%	20.1%	1	2.52	1.92	23.8%	20.1%					
Mar	85	0	0															

TABLE 6b: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-6 BASIN *(continued)*

		One Month Interval		Three Month Interval					Four Month Interval					Six Month Interval				
Mon	Year	Pre-BMP (in)	Post-BMP (in)	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction
Apr	85	2.52	1.92															
May	85	0	0	2	6.24	5.13	17.8%	15.0%						1	14.2	12.74	10.3%	8.7%
Jun	85	1.96	0						2	13.33	12.39	7.1%	6.0%					
Jul	85	4.28	5.13															
Aug	85	1.06	0.63	3	7.96	7.61	4.4%	3.7%										
Sep	85	6.03	6.63															
Oct	85	0.87	0.35						3	2.73	0.98	64.1%	54.2%					
Nov	85	0	0	4	1.86	0.63	66.1%	55.9%						2	4.19	2.33	44.4%	37.5%
Dec	85	0	0															
Jan	86	1.86	0.63															
Feb	86	0	0	1	2.33	1.7	27.0%	22.9%	1	3.15	1.92	39.0%	33.0%					
Mar	86	2.33	1.7															
Apr	86	0	0															
May	86	0.82	0.22	2	9.61	5.1	46.9%	39.7%						1	14.88	12.11	18.6%	15.7%
Jun	86	5.6	3.38						2	12.48	10.88	12.8%	10.8%					
Jul	86	3.19	1.5															
Aug	86	3.6	6	3	5.27	7.01	-33.0%	-27.9%										
Sep	86	0.09	0															
Oct	86	1.58	1.01						3	4.96	3.55	28.4%	24.0%					
Nov	86	0.24	0	4	3.38	2.54	24.9%	21.0%						2	6.23	5.29	15.1%	12.8%
Dec	86	2.71	2.54															
Jan	87	0.43	0															
Feb	87	0	0	1	2.85	2.75	3.5%	3.0%	1	2.85	2.75	3.5%	3.0%					
Mar	87	2.85	2.75															
Apr	87	0	0															
May	87	0	0	2	3.55	2.36	33.5%	28.3%						1	6.84	4.09	40.2%	34.0%
Jun	87	1.61	0.86						2	4.52	2.99	33.8%	28.6%					
Jul	87	1.94	1.5															
Aug	87	0.97	0.63	3	3.29	1.73	47.4%	40.1%										
Sep	87	0	0															
Oct	87	2.32	1.1						3	7.12	5.21	26.8%	22.7%					

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TABLE 6b: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-6 BASIN *(continued)*

		One Month Interval		Three Month Interval					Four Month Interval					Six Month Interval				
Mon	Year	Pre-BMP (in)	Post-BMP (in)	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction
Nov	87	4.28	4.11	4	4.8	4.11	14.4%	12.2%						2	5.48	4.11	25.0%	21.1%
Dec	87	0	0															
Jan	88	0.52	0															
Feb	88	0.34	0	1	0.68	0	100.0%	84.6%	1	0.68	0	100.0%	84.6%					
Mar	88	0	0															
Apr	88	0.34	0															
May	88	0	0	2	6.49	4.88	24.8%	21.0%						1	11.54	9.98	13.5%	11.4%
Jun	88	0.39	0						2	11.54	9.98	13.5%	11.4%					
Jul	88	6.1	4.88															
Aug	88	4.45	4.5	3	5.05	5.1	-1.0%	-0.8%										
Sep	88	0.6	0.6															

Period

1 = FEB ---> APR (DRY)
2 = MAY ---> JUL (WET)
3 = AUG ---> OCT (WET)
4 = NOV ---> JAN (DRY)

Period

1 = FEB ---> MAY (MOSTLY DRY)
2 = JUN ---> SEP (WET)
3 = OCT ---> JAN (MOSTLY DRY)

Period

1 = MAY ---> OCT (WET)
2 = NOV ---> APR (DRY)

TABLE 6c: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-7 BASIN

Mon	Year	One Month Interval Pre-BMP (in)	One Month Interval Post-BMP (in)	Three Month Interval Period	Three Month Interval Pre-BMP (in)	Three Month Interval Post-BMP (in)	Three Month Interval Percent Reduction	Three Month Interval Adjusted Reduction	Four Month Interval Period	Four Month Interval Pre-BMP (in)	Four Month Interval Post-BMP (in)	Four Month Interval Percent Reduction	Four Month Interval Adjusted Reduction	Six Month Interval Period	Six Month Interval Pre-BMP (in)	Six Month Interval Post-BMP (in)	Six Month Interval Percent Reduction	Six Month Interval Adjusted Reduction
Feb	80	2.33	1.63	1	4.56	3.66	19.7%	16.7%	1	7.49	4.66	37.8%	32.0%					
Mar	80	0.95	1.82															
Apr	80	1.28	0.21															
May	80	2.93	1	2	4.3	1.29	70.0%	59.2%						1	8.53	3.33	61.0%	51.6%
Jun	80	0.02	0.02						2	5.38	2.28	57.6%	48.7%					
Jul	80	1.35	0.27															
Aug	80	1.01	0.22	3	4.23	2.04	51.8%	43.8%										
Sep	80	3	1.77															
Oct	80	0.22	0.05						3	1.45	0.25	82.8%	70.0%					
Nov	80	1.23	0.2	4	1.23	0.2	83.7%	70.8%						2	2.33	0.38	83.7%	70.8%
Dec	80	0	0															
Jan	81	0	0															
Feb	81	1.1	0.18	1	1.1	0.18	83.6%	70.7%	1	2.87	0.69	76.0%	64.2%					
Mar	81	0	0															
Apr	81	0	0															
May	81	1.77	0.51	2	2.83	0.85	70.0%	59.2%						1	15.68	12.39	21.0%	17.7%
Jun	81	0.24	0.14						2	13.91	11.88	14.6%	12.3%					
Jul	81	0.82	0.2															
Aug	81	11.92	11.34	3	12.85	11.54	10.2%	8.6%										
Sep	81	0.93	0.2															
Oct	81	0	0						3	2.46	1.93	21.5%	18.2%					
Nov	81	2.46	1.93	4	2.46	1.93	21.5%	18.2%						2	4.36	2.31	47.0%	39.8%
Dec	81	0	0															
Jan	82	0	0															
Feb	82	0.01	0.01	1	1.9	0.38	80.0%	67.7%	1	9.63	7.09	26.4%	22.3%					
Mar	82	1.74	0.33															
Apr	82	0.15	0.04															
May	82	7.73	6.71	2	18.51	16.21	12.4%	10.5%						1	31.82	28.51	10.4%	8.8%
Jun	82	9.26	9.2						2	22.62	20.3	10.3%	8.7%					
Jul	82	1.52	0.3															
Aug	82	3.68	1.86	3	13.31	12.3	7.6%	6.4%										

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TABLE 6c: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-7 BASIN *(continued)*

Mon	Year	One Month Interval Pre-BMP (in)	One Month Interval Post-BMP (in)	Three Month Interval Period	Three Month Interval Pre-BMP (in)	Three Month Interval Post-BMP (in)	Three Month Interval Percent Reduction	Three Month Interval Adjusted Reduction	Four Month Interval Period	Four Month Interval Pre-BMP (in)	Four Month Interval Post-BMP (in)	Four Month Interval Percent Reduction	Four Month Interval Adjusted Reduction	Six Month Interval Period	Six Month Interval Pre-BMP (in)	Six Month Interval Post-BMP (in)	Six Month Interval Percent Reduction	Six Month Interval Adjusted Reduction
Sep	82	8.16	8.94															
Oct	82	1.47	1.5						3	4.46	4.27	4.3%	3.6%					
Nov	82	0	0	4	2.99	2.77	7.4%	6.2%						2	13.13	10.6	19.3%	16.3%
Dec	82	0	0															
Jan	83	2.99	2.77															
Feb	83	7.54	4.89	1	10.14	7.83	22.8%	19.3%	1	10.21	7.86	23.0%	19.5%					
Mar	83	2.59	2.93															
Apr	83	0.01	0.01															
May	83	0.07	0.03	2	8.32	6.08	26.9%	22.8%						1	15.85	13.71	13.5%	11.4%
Jun	83	5.19	3.71						2	12.62	9.34	26.0%	22.0%					
Jul	83	3.06	2.34															
Aug	83	2.64	1.72	3	7.53	7.63	-1.3%	-1.1%										
Sep	83	1.73	1.57															
Oct	83	3.16	4.34						3	5.8	4.71	18.8%	15.9%					
Nov	83	0	0	4	2.64	0.37	86.0%	72.7%						2	6.84	4.89	28.5%	24.1%
Dec	83	2.64	0.37															
Jan	84	0	0															
Feb	84	0	0	1	4.2	4.52	-7.6%	-6.4%	1	9.57	9.36	2.2%	1.9%					
Mar	84	2.33	4.23															
Apr	84	1.87	0.29															
May	84	5.37	4.84	2	7.98	5.33	33.2%	28.1%						1	10.25	7.6	25.9%	21.9%
Jun	84	1.07	0.21						2	4.88	2.76	43.4%	36.7%					
Jul	84	1.54	0.28															
Aug	84	0.08	0.08	3	2.27	2.27	0.0%	0.0%										
Sep	84	2.19	2.19															
Oct	84	0	0						3	0.89	0.14	84.3%	71.3%					
Nov	84	0.89	0.14	4	0.89	0.14	84.3%	71.3%						2	3.22	1.57	51.2%	43.3%
Dec	84	0	0															
Jan	85	0	0															
Feb	85	0	0	1	2.33	1.43	38.6%	32.7%	1	2.44	1.47	39.8%	33.6%					
Mar	85	0.31	0.06															

TABLE 6c: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-7 BASIN *(continued)*

		One Month Interval		Three Month Interval					Four Month Interval					Six Month Interval				
Mon	Year	Pre-BMP (in)	Post-BMP (in)	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction
Apr	85	2.02	1.37															
May	85	0.11	0.04	2	8.76	7.4	15.5%	13.1%						1	14.79	12.34	16.6%	14.0%
Jun	85	4.27	0.96						2	14.46	12.25	15.3%	12.9%					
Jul	85	4.38	6.4															
Aug	85	0.58	0.23	3	6.03	4.94	18.1%	15.3%										
Sep	85	5.23	4.66															
Oct	85	0.22	0.05						3	1.77	0.33	81.4%	68.8%					
Nov	85	0.03	0.03	4	1.55	0.28	81.9%	69.3%						2	4.59	2.59	43.6%	36.8%
Dec	85	0.01	0.01															
Jan	86	1.51	0.24															
Feb	86	0.01	0.01	1	3.04	2.31	24.0%	20.3%	1	4.72	3.37	28.6%	24.2%					
Mar	86	3.03	2.3															
Apr	86	0	0															
May	86	1.68	1.06	2	9.88	5.97	39.6%	33.5%						1	13.49	9.21	31.7%	26.8%
Jun	86	6.56	4.59						2	11.17	8.03	28.1%	23.8%					
Jul	86	1.64	0.32															
Aug	86	2.92	3.07	3	3.61	3.24	10.2%	8.7%										
Sep	86	0.05	0.05															
Oct	86	0.64	0.12						3	4.25	2.49	41.4%	35.0%					
Nov	86	0.02	0.02	4	3.61	2.37	34.3%	29.0%						2	6.73	5.93	11.9%	10.1%
Dec	86	3.2	2.3															
Jan	87	0.39	0.05															
Feb	87	0	0	1	3.12	3.56	-14.1%	-11.9%	1	3.78	3.7	2.1%	1.8%					
Mar	87	3.12	3.56															
Apr	87	0	0															
May	87	0.66	0.14	2	4.94	1.83	63.0%	53.2%						1	10.35	6.97	32.7%	27.6%
Jun	87	2.12	1.3						2	7.15	4.07	43.1%	36.4%					
Jul	87	2.16	0.39															
Aug	87	0.69	0.15	3	5.41	5.14	5.0%	4.2%										
Sep	87	2.18	2.23															
Oct	87	2.54	2.76						3	6.77	6.09	10.0%	8.5%					

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TABLE 6c: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-7 BASIN *(continued)*

		One Month Interval		Three Month Interval					Four Month Interval					Six Month Interval				
Mon	Year	Pre-BMP (in)	Post-BMP (in)	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction
Nov	87	3.4	3.22	4	4.23	3.33	21.3%	18.0%						2	5.89	3.7	37.2%	31.4%
Dec	87	0	0															
Jan	88	0.83	0.11															
Feb	88	0.88	0.11	1	1.66	0.37	77.7%	65.7%	1	1.68	0.39	76.8%	64.9%					
Mar	88	0	0															
Apr	88	0.78	0.26															
May	88	0.02	0.02	2	6.43	4.24	34.1%	28.8%						1	11.91	10.24	14.0%	11.9%
Jun	88	1.4	0.32						2	11.89	10.22	14.0%	11.9%					
Jul	88	5.01	3.9															
Aug	88	5.48	6	3	5.48	6	-9.5%	-8.0%										
Sep	88	0	0															

Three Month Interval — Period

1 = FEB ---> APR (DRY)
2 = MAY ---> JUL (WET)
3 = AUG ---> OCT (WET)
4 = NOV ---> JAN (DRY)

Four Month Interval — Period

1 = FEB ---> MAY (MOSTLY DRY)
2 = JUN ---> SEP (WET)
3 = OCT ---> JAN (MOSTLY DRY)

Six Month Interval — Period

1 = MAY ---> OCT (WET)
2 = NOV ---> APR (DRY)

TABLE 6d: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-8 BASIN

		One Month Interval		Three Month Interval					Four Month Interval					Six Month Interval				
Mon	Year	Pre-BMP (in)	Post-BMP (in)	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction
Feb	80	3.09	1.5	1	5.68	4.59	19.2%	16.2%	1	7.26	5.02	30.9%	26.1%					
Mar	80	0.39	2.13															
Apr	80	2.2	0.96															
May	80	1.58	0.43	2	2.3	0.43	81.3%	68.8%						1	5.86	1.93	67.1%	56.7%
Jun	80	0.11	0						2	4.12	1.5	63.6%	53.8%					
Jul	80	0.61	0															
Aug	80	1.85	0	3	3.56	1.5	57.9%	48.9%										
Sep	80	1.55	1.5															
Oct	80	0.16	0						3	0.96	0	100.0%	84.6%					
Nov	80	0.65	0	4	0.8	0	100.0%	84.6%						2	2.41	0	100.0%	84.6%
Dec	80	0.15	0															
Jan	81	0	0															
Feb	81	1.61	0	1	1.61	0	100.0%	84.6%	1	1.61	0	100.0%	84.6%					
Mar	81	0	0															
Apr	81	0	0															
May	81	0	0	2	3.38	0.86	74.6%	63.0%						1	8.41	3.86	54.1%	45.8%
Jun	81	2.39	0.86						2	8.41	3.86	54.1%	45.8%					
Jul	81	0.99	0															
Aug	81	4.6	1.5	3	5.03	3	40.4%	34.1%										
Sep	81	0.43	1.5															
Oct	81	0	0						3	1.48	0.85	42.6%	36.0%					
Nov	81	1.48	0.85	4	1.48	0.85	42.6%	36.0%						2	1.79	0.85	52.5%	44.4%
Dec	81	0	0															
Jan	82	0	0															
Feb	82	0	0	1	0.31	0	100.0%	84.6%	1	6.45	5.53	14.3%	12.1%					
Mar	82	0.31	0															
Apr	82	0	0															
May	82	6.14	5.53	2	16.56	13.94	15.8%	13.4%						1	27.8	25.44	8.5%	7.2%
Jun	82	9.02	8.41						2	21.06	19.91	5.5%	4.6%					
Jul	82	1.4	0															
Aug	82	4.32	2.75	3	11.24	11.5	-2.3%	-2.0%										

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TABLE 6d: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-8 BASIN *(continued)*

		One Month Interval		Three Month Interval					Four Month Interval					Six Month Interval				
Mon	Year	Pre-BMP (in)	Post-BMP (in)	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction
Sep	82	6.32	8.75															
Oct	82	0.6	0						3	3.38	1.66	50.9%	43.0%					
Nov	82	0	0	4	2.78	1.66	40.3%	34.1%						2	12.9	9.16	29.0%	24.5%
Dec	82	0	0															
Jan	83	2.78	1.66															
Feb	83	6.57	4.5	1	10.12	7.5	25.9%	21.9%	1	10.35	7.5	27.5%	23.3%					
Mar	83	3.42	3															
Apr	83	0.13	0															
May	83	0.23	0	2	7.83	6	23.4%	19.8%						1	17.22	15	12.9%	10.9%
Jun	83	6.91	6						2	12.25	7.5	38.8%	32.8%					
Jul	83	0.69	0															
Aug	83	3.37	1.5	3	9.39	9	4.2%	3.5%										
Sep	83	1.28	0															
Oct	83	4.74	7.5						3	7.55	7.5	0.7%	0.6%					
Nov	83	0	0	4	2.81	0	100.0%	84.6%						2	7.68	6	21.9%	18.5%
Dec	83	2.75	0															
Jan	84	0.06	0															
Feb	84	1.45	1.5	1	4.87	6	-23.2%	-19.6%	1	7.55	6.47	14.3%	12.1%					
Mar	84	2.63	4.5															
Apr	84	0.79	0															
May	84	2.68	0.47	2	7.65	3.47	54.6%	46.2%						1	10.98	7.1	35.3%	29.9%
Jun	84	1.01	0						2	8.3	6.63	20.1%	17.0%					
Jul	84	3.96	3															
Aug	84	0.18	0	3	3.33	3.63	-9.0%	-7.6%										
Sep	84	3.15	3.63															
Oct	84	0	0						3	1.86	1.14	38.7%	32.7%					
Nov	84	1.85	1.14	4	1.86	1.14	38.7%	32.7%						2	5.85	3.82	34.7%	29.3%
Dec	84	0.01	0															
Jan	85	0	0															
Feb	85	0	0	1	3.99	2.68	32.8%	27.8%	1	4.42	2.68	39.4%	33.3%					
Mar	85	0.62	0															

TABLE 6d: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-8 BASIN *(continued)*

		One Month Interval		Three Month Interval					Four Month Interval					Six Month Interval				
Mon	Year	Pre-BMP (in)	Post-BMP (in)	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction
Apr	85	3.37	2.68															
May	85	0.43	0	2	8.96	5.02	44.0%	37.2%						1	15.96	11.02	31.0%	26.2%
Jun	85	3.16	2.44						2	15.4	11.02	28.4%	24.1%					
Jul	85	5.37	2.58															
Aug	85	3.27	3	3	7	6	14.3%	12.1%										
Sep	85	3.6	3															
Oct	85	0.13	0						3	2.11	1.5	28.9%	24.4%					
Nov	85	0	0	4	1.98	1.5	24.2%	20.5%						2	3.49	3	14.0%	11.9%
Dec	85	0.23	0															
Jan	86	1.75	1.5															
Feb	86	0.36	0	1	1.51	1.5	0.7%	0.6%	1	1.51	1.5	0.7%	0.6%					
Mar	86	1.15	1.5															
Apr	86	0	0															
May	86	0	0	2	11.82	8.42	28.8%	24.3%						1	19	14.42	24.1%	20.4%
Jun	86	9.68	8.42						2	18.01	14.42	19.9%	16.9%					
Jul	86	2.14	0															
Aug	86	4.69	4.5	3	7.18	6	16.4%	13.9%										
Sep	86	1.5	1.5															
Oct	86	0.99	0						3	4.77	2.13	55.3%	46.8%					
Nov	86	0	0	4	3.78	2.13	43.7%	36.9%						2	8.4	6.63	21.1%	17.8%
Dec	86	3.09	2.13															
Jan	87	0.69	0															
Feb	87	1.09	0	1	4.62	4.5	2.6%	2.2%	1	5.59	4.5	19.5%	16.5%					
Mar	87	3.53	4.5															
Apr	87	0	0															
May	87	0.97	0	2	4.77	1.25	73.8%	62.4%						1	12.12	7.63	37.0%	31.3%
Jun	87	2.41	1.25						2	8.49	5.75	32.3%	27.3%					
Jul	87	1.39	0															
Aug	87	0.94	0	3	7.35	6.38	13.2%	11.2%										
Sep	87	3.75	4.5															
Oct	87	2.66	1.88						3	7.34	4.16	43.3%	36.6%					

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TABLE 6d: MODIFIED IDMM PUMP RESULTS AT VARIOUS MONTHLY SUMMED INTERVALS

S-8 BASIN *(continued)*

		One Month Interval		Three Month Interval					Four Month Interval					Six Month Interval				
Mon	Year	Pre-BMP (in)	Post-BMP (in)	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction	Period	Pre-BMP (in)	Post-BMP (in)	Percent Reduction	Adjusted Reduction
Nov	87	4.34	2.28	4	4.68	2.28	51.3%	43.4%						2	7.32	3.78	48.4%	40.9%
Dec	87	0	0															
Jan	88	0.34	0															
Feb	88	1.5	0	1	2.64	1.5	43.2%	36.5%	1	2.64	1.5	43.2%	36.5%					
Mar	88	0.75	1.5															
Apr	88	0.39	0															
May	88	0	0	2	9.23	7.77	15.8%	13.4%						1	15.1	10.77	28.7%	24.2%
Jun	88	3.17	1.14						2	15.1	10.77	28.7%	24.2%					
Jul	88	6.06	6.63															
Aug	88	5.87	3	3	5.87	3	48.9%	41.3%										
Sep	88	0	0															

Period

1 = FEB ---> APR (DRY)
2 = MAY ---> JUL (WET)
3 = AUG ---> OCT (WET)
4 = NOV ---> JAN (DRY)

Period

1 = FEB ---> MAY (MOSTLY DRY)
2 = JUN ---> SEP (WET)
3 = OCT ---> JAN (MOSTLY DRY)

Period

1 = MAY ---> OCT (WET)
2 = NOV ---> APR (DRY)

APPENDIX B-3

MEMORANDUM 11-7138-01

November 17, 1992

TO: DISTRIBUTION

FROM: DOUG MERRILL/HONG ZHU

SUBJECT: TOTAL SUSPENDED SOLIDS (TSS) CONCENTRATIONS IN BASIN S-5A AND BASIN S-7 DISCHARGES

Objective

The objective of the analysis presented below is to decide if direct filtration is an applicable technology for the treatment of stormwater discharged at Basin S-5A and Basin S-7 pump stations.

Approach

First, TSS water quality data was examined for Basin S-5A and Basin S-7 discharges for the years 1974-1992. There were only 40 TSS analyses available for samples collected during flow events. However, there were 346 turbidity analyses. The correlation between turbidity and TSS was strong, so estimates of the TSS concentrations were made for flow events for which turbidity data were available. Finally, estimates of the distribution of TSS were made and compared against upper TSS limits for direct filtration found in the literature.

Results

Results of these analyses are discussed below.

Existing TSS Data. TSS water quality data was examined for Basin S-5A and S-7 discharges for the years 1974-1992. The TSS data for flow situations (summarized in Attachment 1) are very limited, about 40 analyses. (Note that S-150 data are included because about 25 percent of S-7 discharge issues through S-150.) The data suggest that TSS loadings are much higher in S-5A discharges than in S-7/S-150 discharges. For example, the average TSS concentration in S-5A discharges was 50 milligrams per liter (mg/L); TSS exceeded 20 mg/L in 10 of 11 samples. In contrast, the average TSS concentration in S-7/S-150 discharges was 7 mg/L; 28 of 29 samples had TSS concentrations less than 20 mg/L.

TSS/Turbidity Correlations for Flow Events. There is much more turbidity data available than TSS data. It is appropriate to estimate the TSS data with the measured turbidity data if a correlation exists between them. Therefore, the correlations between TSS and turbidity were investigated. It was found that linear correlations exist for TSS and turbidity for all three discharges. The correlation plots are presented in Attachment 2, and the correlation equation and appropriate parameters are presented below:

$$TSS = m * (Turbidity) + b \quad (1)$$

Discharge Station	m	b	R^2	Number of Samples
S-5A	1.29	13.8	0.87	11
S-7	1.01	1.43	0.84	16
S-150	0.48	1.12	0.90	13

Overall TSS/Turbidity Correlations. The data base contains water quality information for samples collected during flow events, when there were no flows, when flows were reversed, and when the flow regimes were not identified. The data base for all these samples is relatively large compared to the data base for samples collected during flow events. It was decided to use this larger database. Therefore, it was assumed that the correlation between TSS and turbidity is independent of flow situations. That is, there should be a correlation between TSS and turbidity for all situations (no flow, flow not identified, flow, and reverse flow). By assuming so, there is a larger data base to establish a more representative correlation equation for TSS and turbidity. Attachment 3 shows the correlation plots for all situations. The correlation parameters (to be used with Equation 1) are presented below:

Discharge Station	m	b	R^2	Number of Samples
S-5A	1.47	2.99	0.89	35
S-7	1.02	0.78	0.84	29

Correlations for Station S-150 were not used because Station S-150 discharge volumes have historically been small compared to Station S-7 discharges (about 25 percent). Station S-150 data could be worked up later, if so desired.

Estimating TSS Distributions. TSS concentrations were projected for flow events at Stations S-5A and S-7, using turbidity data collected during flow events, Equation 1, and the overall "m" and "b" parameters shown directly above. The estimated data was ranked and the percentile of distribution calculated. The distribution plots are shown in Attachment 4.

The following table summarizes the distribution results:

Discharge Station	Projected TSS, mg/L 50 Percent	90 Percent	95 Percent
S-5A	19	40	58
S-7	6	14	16

Ninety-five percent of the projected S-5A TSS concentrations are lower than 58 mg/L, while 95 percent of the projected S-7 TSS concentrations are lower than 16 mg/L.

When Is Direct Filtration Appropriate? The general literature sends mixed messages about when direct filtration can be applied. Montgomery's textbook[1] indicates direct filtration is appropriate when TSS concentrations are below about 20 to 50 mg/L. One source[2] indicates that turbidity and color are two interrelated criteria. If color is low, turbidity as high as 200 NTU can still be suitable for direct filtration treatment; if the turbidity is low, the color can be as high as 100 color units. A third source[3] indicated direct filtration can be used to achieve an 0.1 NTU turbidity goal if influent turbidity is below 10 NTU, color is below 15 units, and the algae clump count is below 1,000 units per milliliter.

Another way to identify the possibility of direct filtration is to look at the coagulant dosages. If the coagulant dosages (alum) are below 6 to 7 mg/L, the water is generally suitable for direct filtration treatment. If the coagulant dosages are higher than 15 mg/L, direct filtration treatment is less feasible.[4] However, problems arising from relatively high coagulant dosages can be overcome by designing a filter with more storage and a capacity for greater loads.[4] This latter statement suggests that direct filtration is not impossible when chemical doses and TSS loadings are high; however, direction filtration may not be economical in such situations.

In summary, cut-off limits for direct filtration are poorly defined. It is clear, however, that discharges from Stations S-150 and S-7 are well below any such limits. Therefore, direct filtration could be applied to Station S-150 and S-7 discharges. Applicability of direct filtration to discharges from Station S-5A is much more open to question. For example, it is estimated that TSS concentrations would exceed a 20 mg/L limit about 50 percent of the time and a 50 mg/L limit about 8 percent of the time. The question as to whether direct filtration is practical for S-5A could be resolved by an economic comparison of direct filtration versus sedimentation plus filtration.

Conclusions

1. TSS concentrations in Station S-5A discharges are greater than those in Stations S-7 and S-150 discharges.

2. TSS concentrations in Stations S-7 and S-150 discharges are far below the cut-off limits found in the general literature. Therefore, direct filtration appears to be practical option for these discharges.

3. TSS concentrations in S-5A discharges sometimes exceed cut-off limits found in the literature. Direct filtration appears to be possible, even if TSS loads and chemical doses are high. However, direct filtration may not be economical under these circumstances. Resolution of the question of the practicality of direct filtration for treating Station S-5A discharges might best come from economic comparisons of direct filtration versus sedimentation plus filtration.

References

1. James M. Montgomery, Consulting Engineers, Inc., Water Treatment Principles and Design. John Wiley and Sons, New York. 1985.

2. Kowamura, S. "Design and Operation of High Rate Filters." Journal AWWA, 67:10:535, July 1977.

3. McCormick, R.F. and King, P.H. "Factors that Affect Use of Direct Filtration in Treating Surface Water." Journal AWWA, 74:5:234, May 1982.

4. Wagner, E.G. and Hudson, H.E., Jr. "Low-Dosage High-Rate Direct Filtration." Journal AWWA, 74:5:256, May 1982.

DTM:HZ:lp
Attachments

Distribution:
Spencer Forrest, Orlando
C. Zachary Fuller, Orlando
Bob Mills, Orlando
Jim Nissen, Atlanta
Joe Wong, Pleasant Hill

Attachment 1

SX	Basin S-5A Flow Code = 1 Date	Time	TSS, mg/L	Turbidity, NTU	rtho P, mg/L	Total P, mg/L	Flow, mgd
CAMB-9518	01/21/83	10:14	31.0	5.7	0.140	0.287	
CAMB-9519	01/21/83	10:20	54.0	6.8	0.066	0.235	
CAMB-9875	09/07/83	08:15	39.6	15.3	0.138	0.314	
CAMB-A164	04/03/84	09:00	33.0	16.0	0.110	0.177	
CAMB-A290	07/23/84	09:29	13.5	7.9	0.276	0.329	
CAMB-A385	10/02/84	00:02	20.0	13.5	0.142	0.411	
CAMB-A664	04/16/85	08:33	41.0	35.0	0.089	0.203	
CAMB-A778	07/24/85	08:44	30.0	23.0	0.122	0.218	
CAMB-D601	10/15/90	09:06	152.0	97.0	0.096	0.295	
CAMB-D987	04/15/91	09:14	91.0	66.0	0.192	0.367	
CAMB-F457	06/29/92	10:09	44.0	23.0	0.185	0.253	

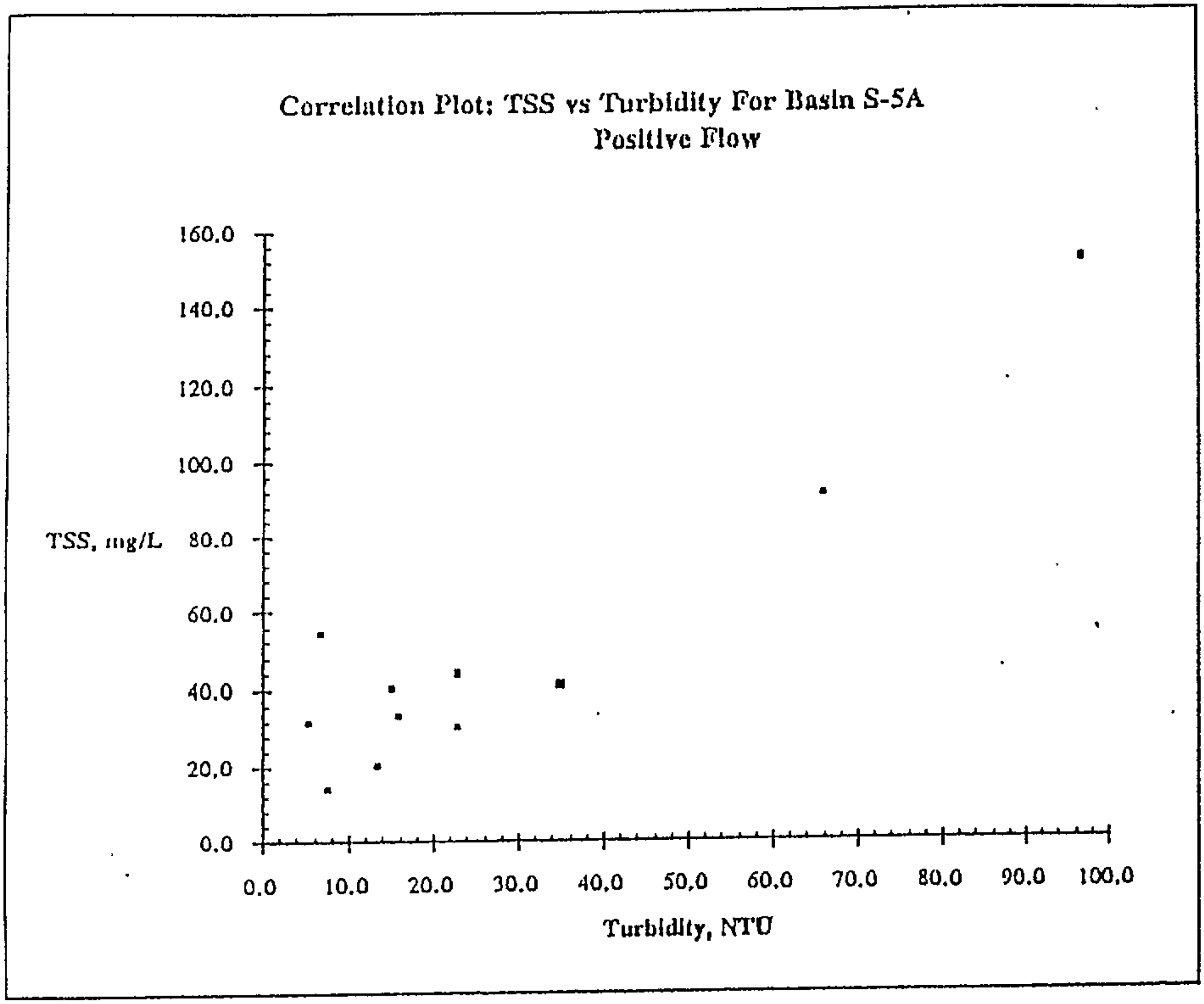
Positive Flows

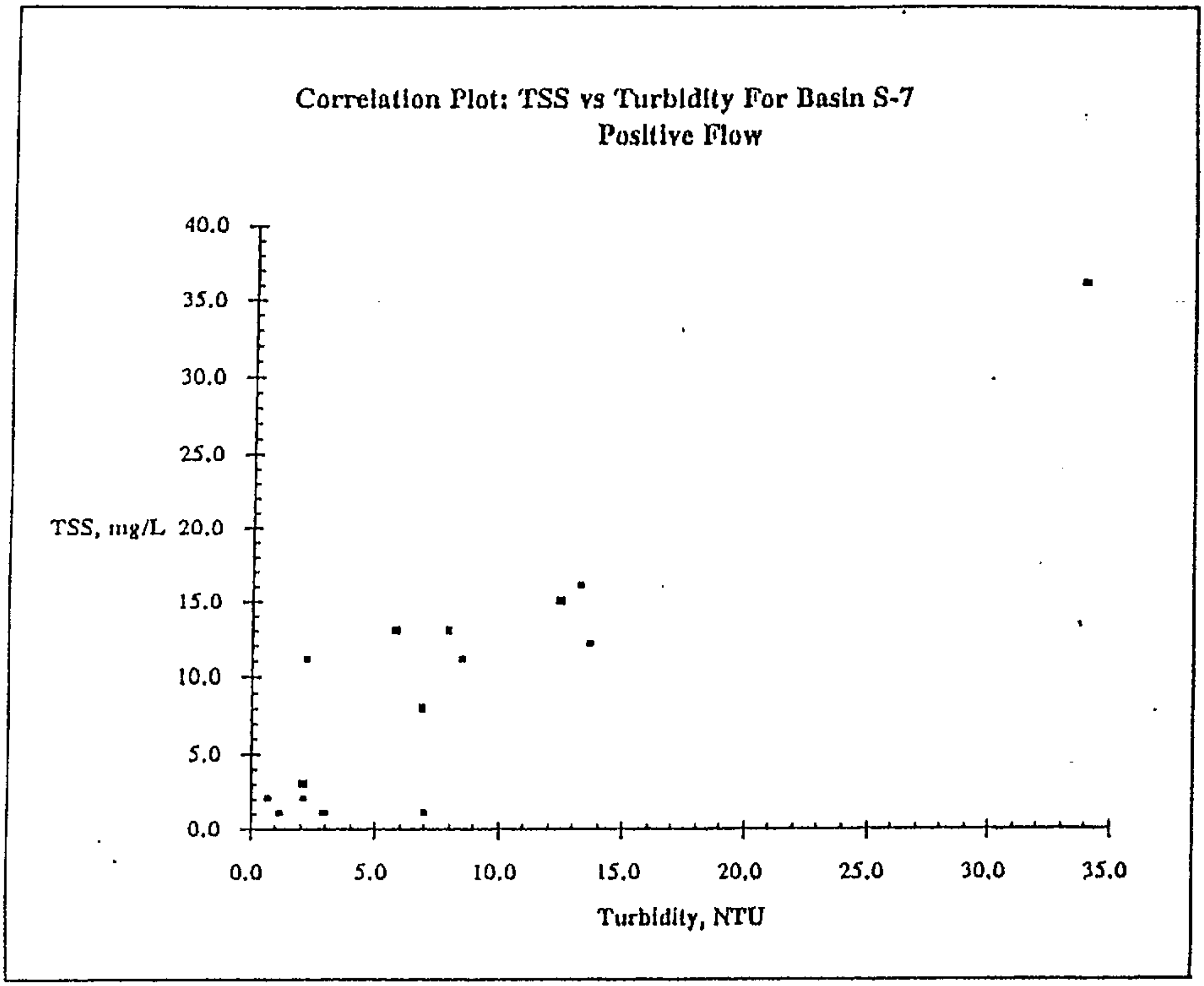
SX	Basin S-7 Date	Time	TSS, mg/L	Turbidity, NTU	rtho P, mg/L	Total P, mg/L	Flow, mgd
CAMB-9876	09/07/83	09:24	13.0	5.8	0.011	0.050	
CAMB-A165	04/03/84	10:08	12.0	13.7	0.022	0.066	
CAMB-A292	07/23/84	10:46	15.0	12.5	0.082	0.104	
CAMB-A387	10/02/84	00:03	3.0	2.2	0.049	0.120	
CAMB-A666	04/16/85	10:10	36.0	34.0	0.093	0.172	
CAMB-A781	07/24/85	11:25	16.0	13.4	0.028	0.085	
CAMB-A857	10/02/85	09:20	13.0	8.0	0.024	0.091	
CAMB-A990	01/21/86	09:31	2.0	0.8	0.042	0.061	
CAMB-B178	06/11/86	10:50	1.0	1.3	0.081	0.104	
CAMB-B940	01/13/88	10:00	2.0	2.2	0.023	0.049	
CAMB-C194	04/19/88	10:00	1.0	7.1	0.055	0.077	
CAMB-D603	10/15/90	10:25	11.0	8.6	0.083	0.098	
CAMB-E267	07/22/91	13:38	11.0	2.3	0.011	0.037	
CAMB-F257	04/28/92	10:33	3.0	2.1	0.018	0.044	
CAMB-F464	06/29/92	12:40	8.0	7.0	0.189	0.214	
CAMB-F515	07/06/92	10:49	1.0	3.0	0.146	0.186	

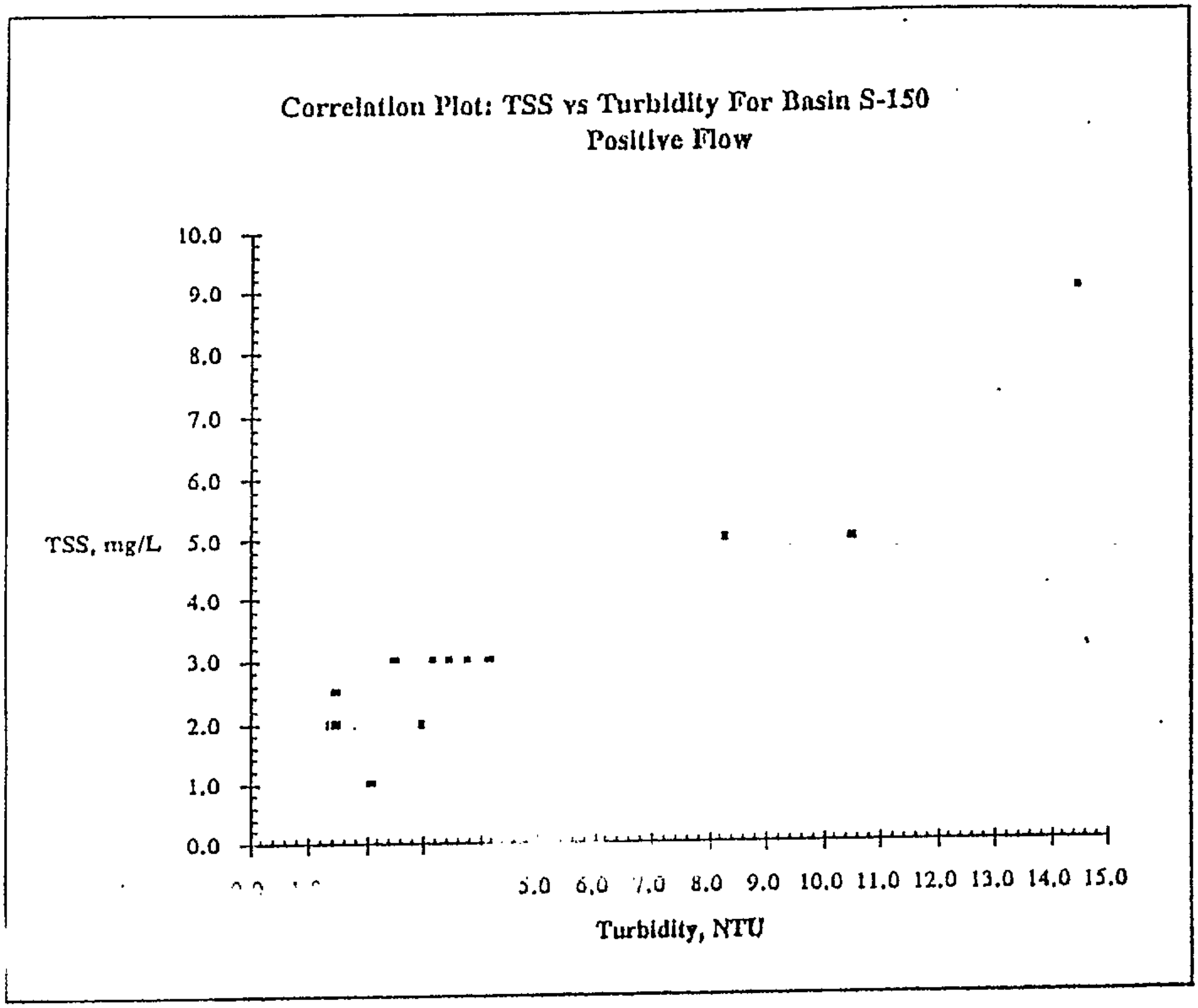
Positive Flows

SX	Basin S-150 Date	Time	TSS, mg/L	Turbidity, NTU	rtho P, mg/L	Total P, mg/L	Flow, mgd
CAMB-A166	04/03/84	10:19	9.0	14.5	0.021	0.062	
CAMB-A293	07/23/84	10:56	2.5	1.5	0.069	0.075	
CAMB-A388	10/02/84	00:03	2.0	1.4	0.051	0.120	
CAMB-A535	01/22/85	09:02	3.0	4.2	0.005	0.021	
CAMB-A667	04/16/85	10:29	3.0	3.8	0.031	0.040	
CAMB-C718	04/17/89	10:46	5.0	8.3	0.050	0.097	
CAMB-C878	07/24/89	10:20	3.0	3.5	0.100	0.140	
CAMB-D160	01/24/90	09:50	3.0	3.2	0.010	0.036	
CAMB-D295	04/16/90	10:49	5.0	10.5	0.012	0.048	
CAMB-D450	07/23/90	12:20	2.0	3.0	0.061	0.084	
CAMB-E037	04/29/91	15:55	3.0	2.5	0.041	0.064	
CAMB-E938	01/22/92	12:45	1.0	2.1	0.024	0.044	
CAMB-F640	07/22/92	10:25	2.0	1.5	0.007	0.032	

Attachment 2

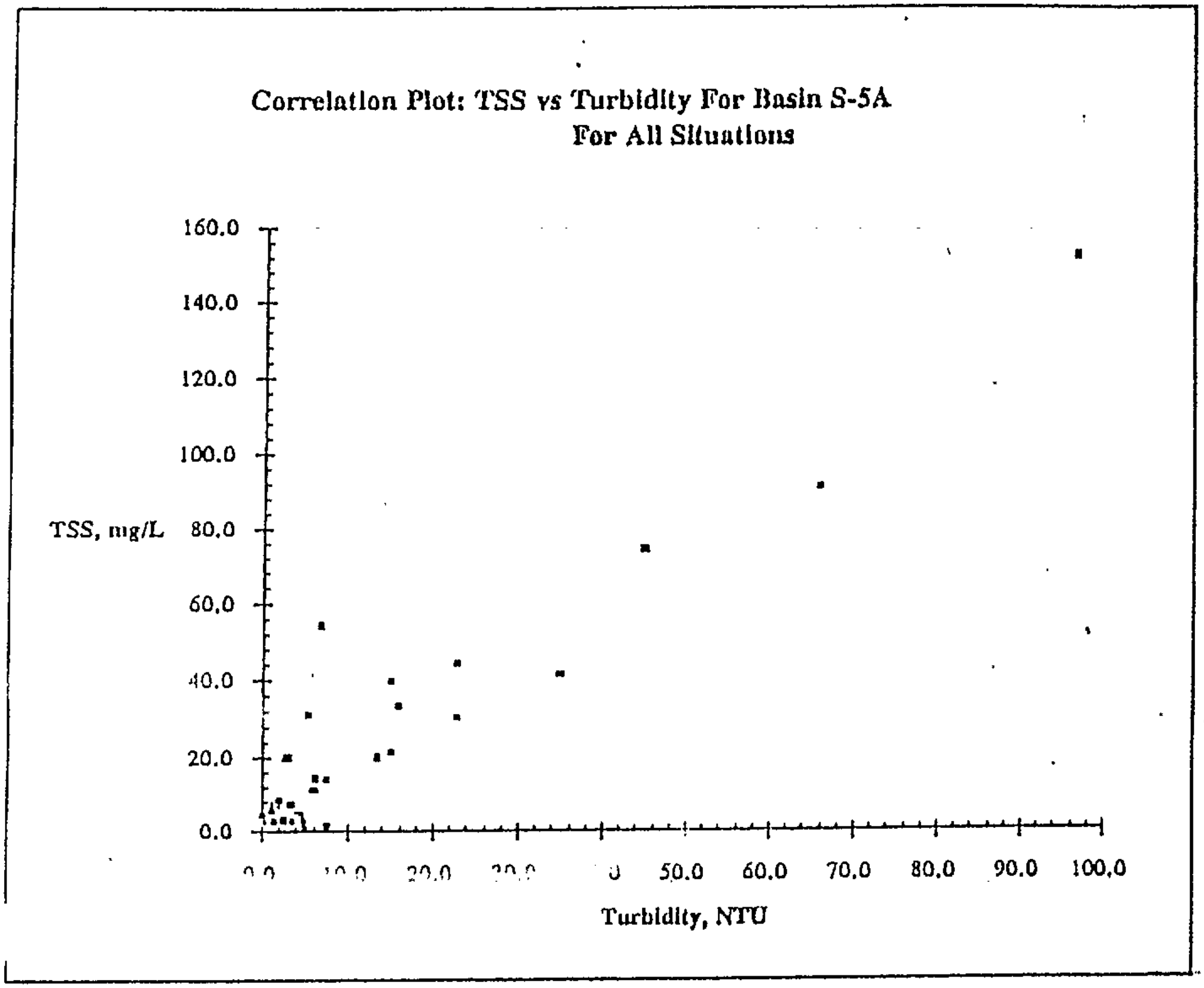

Correlation Plot: TSS vs Turbidity For Basin S-5A
Positive Flow
TSS, mg/L
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
Turbidity, NTU

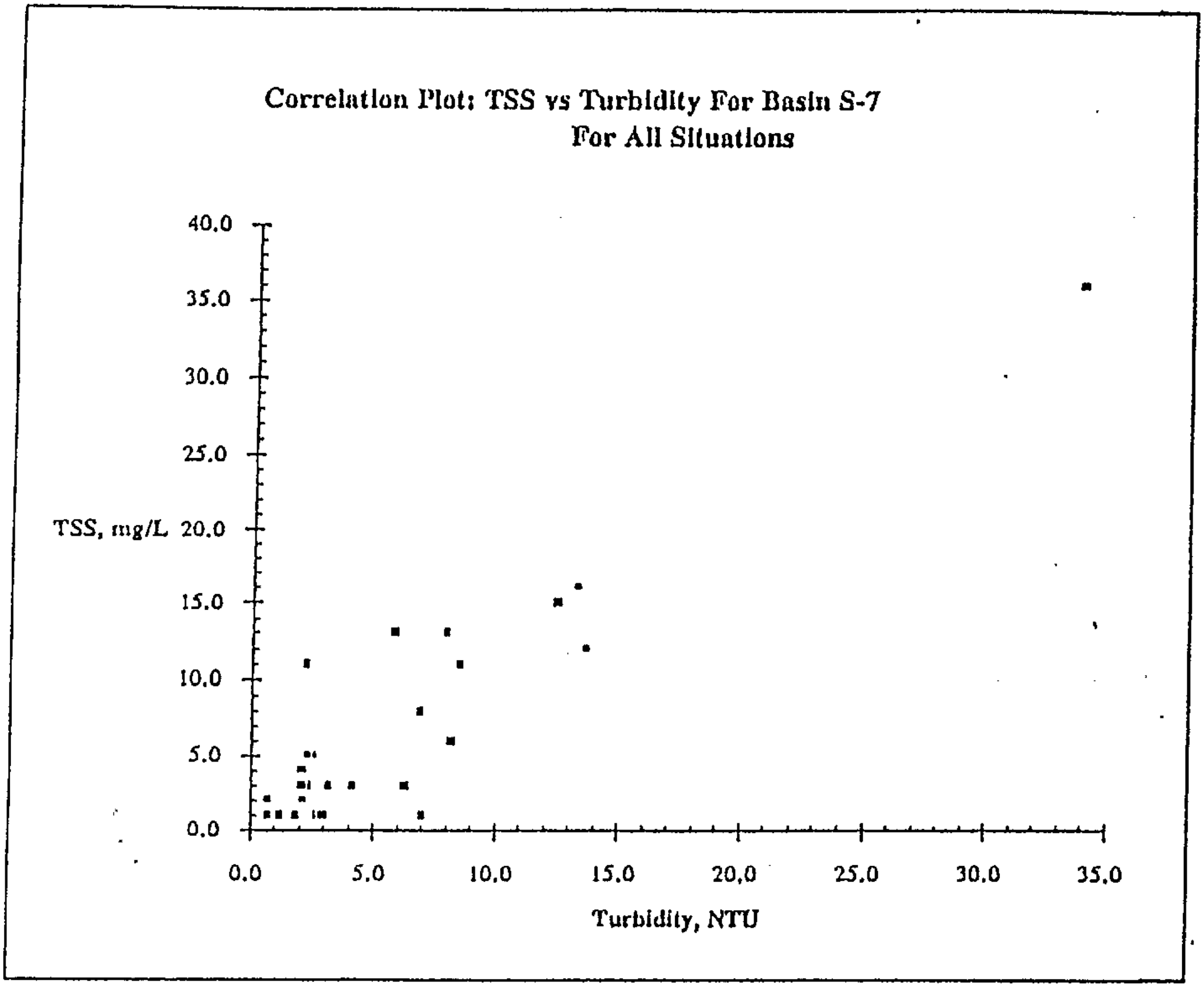

Correlation Plot: TSS vs Turbidity For Basin S-7
Positive Flow
TSS, mg/L
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
Turbidity, NTU



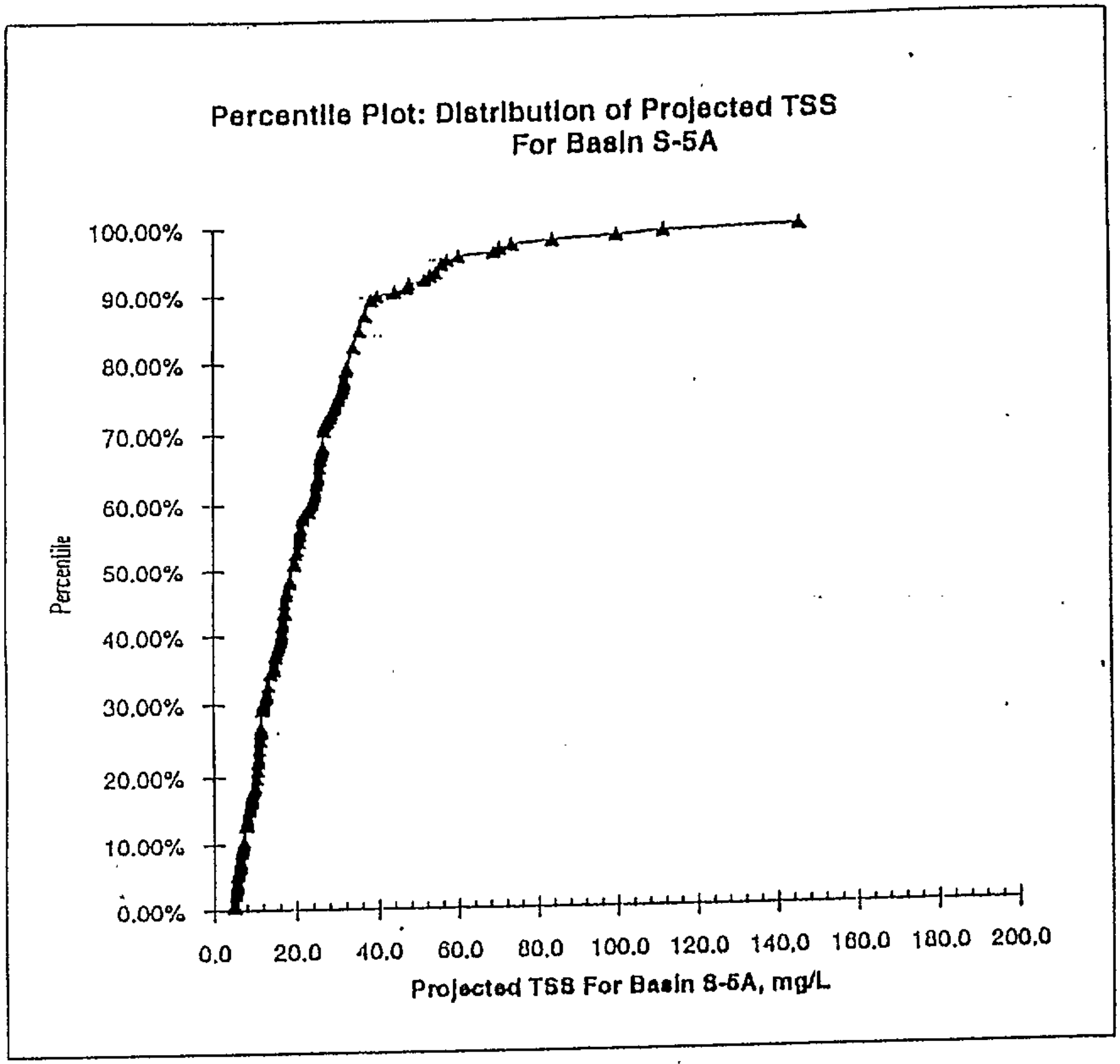
Correlation Plot: TSS vs Turbidity For Basin S-150
Positive Flow
TSS, mg/L
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
Turbidity, NTU

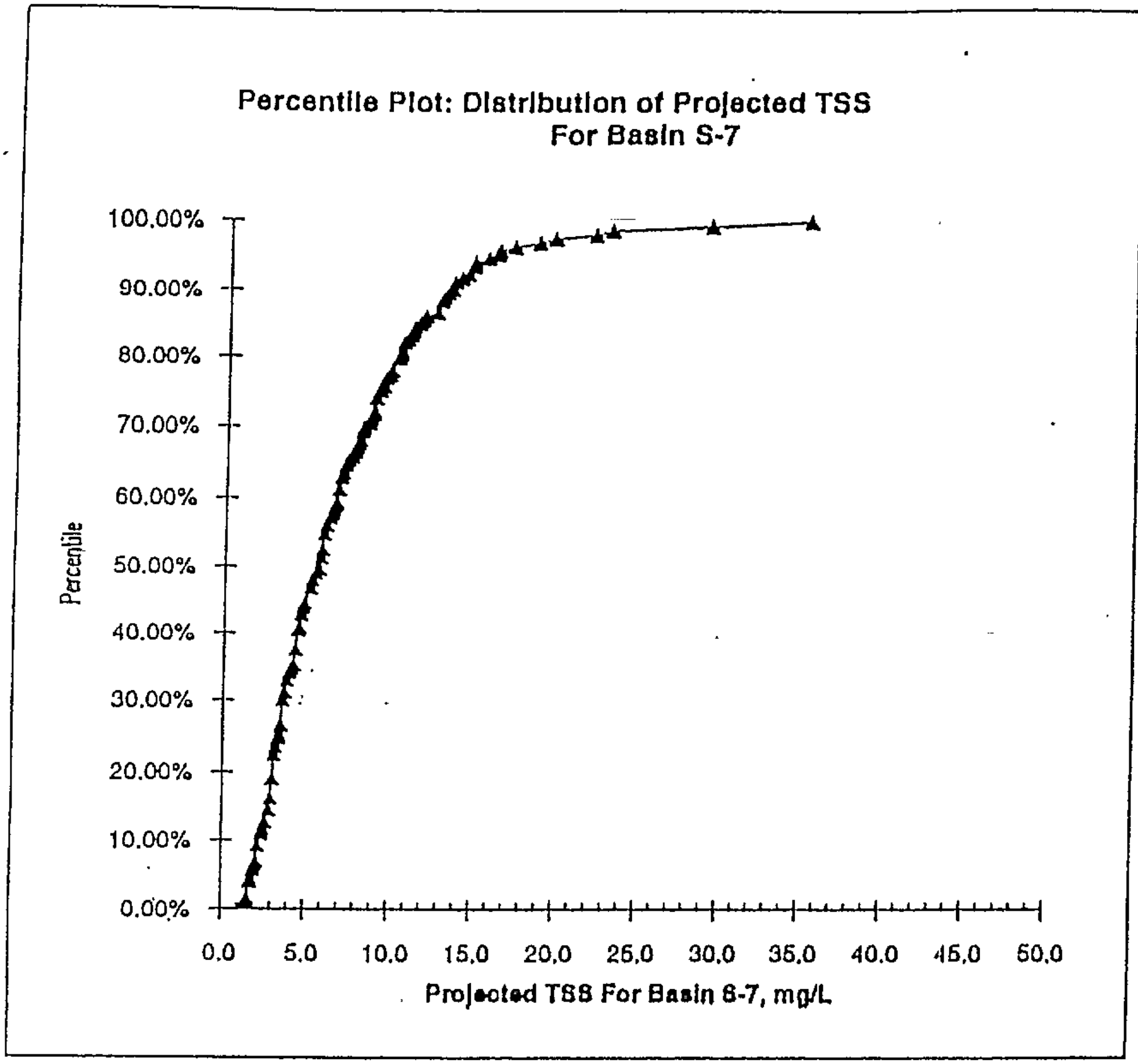
Attachment 3


Correlation Plot: TSS vs Turbidity For Basin S-5A
For All Situations
TSS, mg/L
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
50.0
60.0
70.0
80.0
90.0
100.0
Turbidity, NTU


Correlation Plot: TSS vs Turbidity For Basin S-7
For All Situations
TSS, mg/L
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
Turbidity, NTU

Attachment 4


Percentile Plot: Distribution of Projected TSS
For Basin S-5A
Percentile
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
Projected TSS For Basin S-5A, mg/L


Percentile Plot: Distribution of Projected TSS
For Basin S-7
Percentile
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
Projected TSS For Basin S-7, mg/L

TECHNICAL MEMORANDUM NO. 3 22-7518-01

May 11, 1993

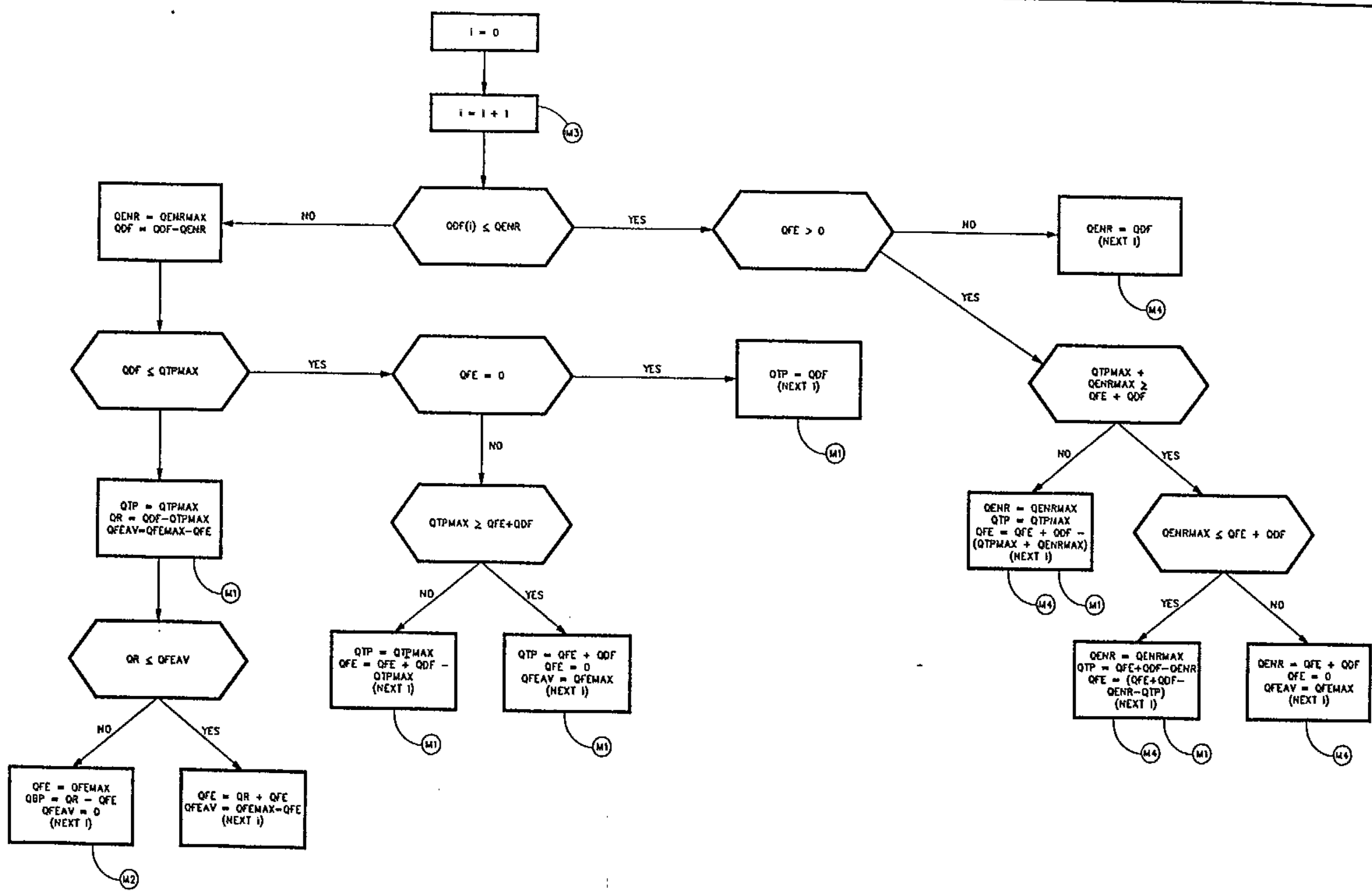
TO: FILE

FROM: C. ZACHARY FULLER, P.E., SPENCER B. FORREST, RICHARD J. JUNNIER

SUBJECT: FLOW EQUALIZATION/TREATMENT PLANT SIZING, CONCEPTUAL UNIT PROCESS DESIGN

Flow Equalization Basin/Direct Filtration Plant Sizing

A computer model was written that uses daily flow and phosphorus (P) load data to compute the optimal flow equalization basin/direct filtration treatment plant combination for each basin. The premise of the model is based on determining the treatment plant capacity necessary to reach the long-term "blended" goal of 0.05 mg/L P in waters from the EAA basins into the Water Conservation Areas (WCAs). Flow equalization is included because it was determined that equalizing flows increases treatment plant utilization during treatment periods and thus reduces "down-time." In addition, flow equalization provides additional benefits of particulate P removal within the basin (although the exact extent of flow equalization benefits are not able to be determined in a study such as this). In essence, the model computes a mass balance around the treatment plant assuming the treatment plant technology can reach a finished water quality of 0.10 mg/L P (this has been demonstrated). Figure 3-1 presents a general flow-chart of the model used in this study. Table 3-1 presents a list defining the primary variables found in Figure 3-1.



Brown and Caldwell
Consultants
ORLANDO, FLORIDA

Figure 3–1
Treatment Plant Optimization Model Flowchart

Table 3-1 Model Variables

Variable	Definition
i	Counter.
QDF	Daily flow from basin.
QENR (Basin S-5A only)	Quantity of flow treated by ENR on a given day.
QENRMAX (Basin S-5A only)	Maximum allowable flow to ENR.
QFE	Quantity of water in flow equalization basin on any given day.
QFEMAX	Flow equalization basin volume.
QFEAV	Available volume in flow equalization basin on any given day.
QTP	Quantity of flow treated by treatment plant on a given day.
QTPMAX	Treatment plant size.
QR	Residual flow after the treatment plant and the ENR (Basin S-5A only) are at maximum capacity.
QBP	Quantity of water not be treated by the treatment plant or the ENR (Basin S-5A only) and not stored in the flow equalization basin. This water passes through the flow equalization basin and is then discharged.
M1	Mass of phosphorus in waters from treatment plant.
M2	Mass of phosphorus in waters from flow equalized, discharged flows.
M3	Mass of phosphorus influent from basin.
M4	Total mass of phosphorus in waters from ENR.

To arrive at the optimal treatment capacity sizes, treatment plant and flow equalization basin sizes were varied until two constraints were satisfied: (1) the long-term "blended" goal of 0.05 mg/L was reached (i.e., the treatment plant was treating enough flow), and (2) essentially all of the flow influent to the flow equalization basin was treated over the period of record 1/1/79 to 9/30/88 (thus not permanently "storing" any significant amount of P in the equalization basin). In addition to using this method for sizing the flow equalization basin and the treatment plant, the numerical analysis of flows and P loads on a daily basis allowed additional pertinent information to be calculated, for example: number of days the treatment plant is on-line, average amount of flow treated, number of positive flow days over the period of record, etc. Basin S-5A presented a special case where the Everglades Nutrient Removal (ENR) Project is used to treat flows to the extent possible. Appendix A-3 contains optimal model runs from each of the basins.

It is important to note that the "optimal" direct filtration treatment plant capacities (and associated flow equalization basin areas) are determined both with and without the assumed 35 percent reduction in particulate P due to sedimentation within the flow equalization basins (as discussed in Technical Memorandum No. 2). Table 3-2 presents treatment plant capacity and flow equalization basin sizing performed with and without the particulate P reduction assumption.

Table 3-2 Optimal Flow Equalization Basin/Treatment Plant Capacities

Location	FE Basin Area/Treatment Plant Capacity with FE Basin Reductions[a]	FE Basin Area/Treatment Plant Capacity without FE Basin Reductions
Basin S-5A	2700 acres, 200 MGD	2800 acres, 260 MGD
Basin S-6	1700 acres, 150 MGD	1700 acres, 190 MGD
Basin S-7	1400 acres, 130 MGD	1700 acres, 190 MGD
Basin S-8	2400 acres, 340 MGD	2800 acres, 450 MGD

[a] 35 percent reduction in particulate P and TSS assumed due to flow equalization effects.

Combining bench-scale testing results (process recommendation, dosage types and amounts, etc.) with optimal flow equalization basin and direct filtration treatment plant capacities, sizes and quantities of the unit processes were computed. The basis of design table were computed for the flow equalization basin and treatment plant sizes determined using the TSS and particulate P reduction assumption. Appendix B-3 contains details of an earlier TSS investigation performed to statistically determine TSS levels.

Conceptual Unit Process Design

Table 3-3 presents the basis of design table for the flow equalization/direct filtration technology for each of the four (4) basins (employing the flow equalization basin TSS and particulate P reduction assumption). Treatment plant capacities and flow equalization volumes were determined from the model as explained above. The basis of design table presents the major process units used in the treatment system for each basin. Critical data such as number of units, equipment type and capacity, chemical dosage requirements, land area and solids handling requirements are provided for each unit process. In addition, these data reflect the following: (1) changes in unadjusted influent flows and P loads (both magnitude and flow and P loading patterns), (2) diversion of part of Basin S-5A flows to the Everglades Nutrient Removal (ENR)

Project, and (3) incorporation of bench-scale test results in process calculations. The data in the basis of design table are used for purposes of determining reasonable capital and O&M cost estimates consistent with the present level of analysis.

Process Flowsheet/General Site Layouts

Figure 3-2 presents a general process flowsheet identifying the treatment process envisioned at the direct filtration treatment plants. Figure 3-3 through Figure 3-6 present general site layouts for each of the four basins, respectively. These site layouts show preliminary location and orientation of flow equalization basin and direct filtration treatment plants. In addition, major flow control facilities are indicated where appropriate. Influent and finished water flow control analyses for the flow equalization basins were taken from the B&M Conceptual Design of STAs report of March, 1992.

E:\7518\TMEMOS\7518TM3.SBF

Table 3-3 Basis of Design for Direct Filtration

Item	Basin S5A	Basin S6	Basin S7	Basin S8
Basin Data				
Flow, million gals				
Maximum annual	107,291	74,500	90,460	124,622
Minimum annual	27,684	20,791	19,040	4,535
Average annual	69,946	40,186	57,625	66,318
Flow, acre-ft				
Maximum annual	329,242	228,617	277,593	382,426
Minimum annual	84,954	63,801	58,428	13,916
Average annual	214,642	123,318	176,833	203,509
P Concentration, mg/L				
Maximum annual	0.255	0.388	0.171	0.318
Minimum annual	0.145	0.081	0.060	0.061
Average	0.211	0.167	0.112	0.183
TSS Concentration, mg/L				
50th percentile	19	12	6	13
Plant Data				
Percent of days on line	45	55	71	53
Percent basin flow treated	44	70	54	80
Flow, mgd				
Maximum	200	150	130	340
Minimum	0	0	0	0
Average				
All days	84	77	85	145
When operating	192	144	123	282
Maximum year				
Total plant flow, MG	46,886	52,299	48,939	99,448
Treatment Plant Influent Pumps				
Number (1 spare)	4	3	3	6
Capacity each pump, gpm	46,293	52,080	45,136	47,219
TDH each, ft	25	25	25	25
Flow Equalization Basin Data				
Surface area, acres	2,700	1,700	1,400	2,400
Maximum water depth, ft	8	8	8	8
Volume, million gals	7,039	4,432	3,650	6,257
acre-ft	21,600	13,600	11,200	19,200
Storage at peak plant flow, days	35	30	28	18
FE Basin Influent pump station capacity, mgd	3,103	1,891	1,610	2,696
FE Basin Effluent/Treatment Plant Influent				
P Concentration, mg/L				
Maximum annual	0.219	0.327	0.135	0.227
Minimum annual	0.124	0.068	0.047	0.044
Average	0.181	0.141	0.088	0.131
TSS Concentration, mg/L				
50th percentile	12	8	4	8

Table 3-3 Basis of Design for Direct Filtration (continued)

Item	Basin S5A	Basin S6	Basin S7	Basin S8
Flow Equalized/Treatment Plant Bypass	Gated Spillway	Gated Spillway	Gated Spillway	Gated Spillway
Chemical addition systems				
Alum				
Form	50% Solution	50% Solution	50% Solution	50% Solution
Dose, mg/L as Al				
Average	8	7	6	6
Maximum	10	10	8	8
Pumps				
Number (1 spare)	4	3	3	6
Capacity, each, gpm	8	9	6	6
Storage tanks				
Volume, gals	500,000	400,000	300,000	700,000
Liner	Rubber	Rubber	Rubber	Rubber
Storage time at peak feed rates, wks	2	2	2	2
Polymer				
Form	Anionic 2% Solution	Anionic 2% Solution	Anionic 2% Solution	Anionic 2% Solution
Dose, mg/L				
Average	0.5	0.5	0.5	0.5
Pumps				
Number (1 spare)	2	2	2	3
Capacity, each, gpm	4	3	3	4
Daily Solution tank, gals	7,000	5,000	4,500	12,000
Storage tanks	Supplied by vendor	Supplied by vendor	Supplied by vendor	Supplied by vendor
Lime				
Form	5% Slurry	5% Slurry	5% Slurry	5% Slurry
Dose, mg/L as CaO				
Average	16	16	9	8
Maximum	20	23	12	11
Slakers				
Number (1 spare)	2	2	2	2
Capacity, each, lbs CaO/hr	1,390	1,199	524	1,264
Pumps				
Number (1 spare)	4	3	2	4
Capacity, each, gpm	15	20	17	14
Storage silos				
Silo volume, ft^3	8,000	7,000	3,000	7,000
Storage time at peak feed rates, wks	2	2	2	2

Table 3-3 Basis of Design for Direct Filtration (continued)

Item	Basin S5A	Basin S6	Basin S7	Basin S8
Rapid mixing	Influent-pump mixing	Influent-pump mixing	Influent-pump mixing	Influent-pump mixing
Flocculators				
Number, in parallel	2	2	2	3
Compartments per flocculator	4	4	4	4
Volume per compartment, gal	249,580	187,697	160,157	244,713
Total detention time at average operating flow, mins	15	15	15	15
Velocity gradient, sec^1				
Minimum	25	25	25	25
Maximum	55	55	55	55
Maximum power input per tank, HP	5	4	4	5
Material of construction	Concrete	Concrete	Concrete	Concrete
Filtration				
Filters (low rate system)				
Number of filter banks, in parallel	2	2	2	2
Filter beds per filter bank	11	8	7	17
Surface area per bed, ft^2	1,296	1,296	1,296	1,296
Material of construction	Concrete	Concrete	Concrete	Concrete
Width x length, ft	24 x 54	24 x 54	24 x 54	24 x 54
Filter rate, gpm/ft^2				
Maximum	6.0	6.0	6.0	6.0
Average, when opertating	5.8	5.8	5.7	5.0
Filters (high rate system)				
Number of filter banks, in parallel	2	2	2	2
Filter beds per filter bank	7	5	5	10
Surface area per bed, ft^2	1,296	1,296	1,296	1,296
Material of construction	Concrete	Concrete	Concrete	Concrete
Width x length, ft	24 x 54	24 x 54	24 x 54	24 x 54
Filter rate, gpm/ft^2				
Maximum	11.0	11.0	11.0	11.0
Average, when opertating	10.5	10.6	10.4	9.1

Table 3-3 Basis of Design for Direct Filtration (continued)

Item	Basin S5A	Basin S6	Basin S7	Basin S8
Filter Media				
Top layer				
Material	Activated Carbon	Activated Carbon	Activated Carbon	Activated Carbon
Effective size, mm	3.3	3.3	3.3	3.3
Uniformity coefficient	1.46	1.46	1.46	1.46
Depth, in	14	14	14	14
Middle layer				
Material	Anthracite	Anthracite	Anthracite	Anthracite
Effective size, mm	1.73	1.73	1.73	1.73
Uniformity coefficient	1.32	1.32	1.32	1.32
Depth, in	57	57	57	57
Bottom layer				
Material	Quartz Sand	Quartz Sand	Quartz Sand	Quartz Sand
Effective size, mm	0.87	0.87	0.87	0.87
Uniformity coefficient	1.28	1.28	1.28	1.28
Depth, in	24	24	24	24
Available headloss increase, ft	7	7	7	7
Method of flow control	Flow control valve	Flow control valve	Flow control valve	Flow control valve
Underdrain	Block	Block	Block	Block
Backwash system				
Clear well				
Number	1	1	1	2
Volume, each, gals	250,000	250,000	250,000	250,000
Depth, ft	10	10	10	10
Surface area, acres	0.08	0.08	0.08	0.08
Material of construction				
Backwash				
Maximum rate, gpm/ft^2	31	31	31	31
Number of pumps (1 spare)	2	2	2	4
Capacity, each, gpm/ft^2	20,088	20,088	20,088	20,088
Air scour				
Capacity, each, scfm	2,592	2,592	2,592	2,592
Number of compressors (1 spare)	2	2	2	4
Rate, scfm/ft^2	4	4	4	4
Washwater reclamation basin/thickener				
Storage basin area, acres	4.5	3.1	2.0	5.9
Depth of basin,ft	15	15	15	15
Number of basin cells	4	4	4	4
Acres per cell	1.12	0.77	0.50	1.46
Reclaimed washwater returned to plant	Gravity Flow	Gravity Flow	Gravity Flow	Gravity Flow
Percent solids, thickened sludge	5	5	5	5
Number of dredges	1	1	1	1
Capacity each dredge, gpm	1,122	772	501	1,467
Material of basin construction	Earth	Earth	Earth	Earth

Table 3-3 Basis of Design for Direct Filtration (continued)

Item	Basin S5A	Basin S6	Basin S7	Basin S8
Dedicated land disposal				
Spreading season, mos	11	11	11	11
Sludge production, tons dry solids per year				
Maximum	8,092	7,366	5,340	12,510
Average	5,276	3,974	3,402	6,657
Maximum application rate, tons dry solids per acre per year	35.5	35.5	35.5	35.5
Number of sections	6	6	4	9
Area per section, acres	38.0	34.6	37.6	39.2
Sludge storage tanks				
Number	6	6	4	9
Capacity, each, gals	7,500	7,500	7,500	7,500
Subsurface sludge injection vehicles				
Number, trucks	2	2	2	3
Spreading capacity each, gal/day	120,000	120,000	120,000	120,000
Land requirements, acres				
Low-rate system	2,934	1,912	1,553	2,761
High-rate system	2,931	1,909	1,550	2,758

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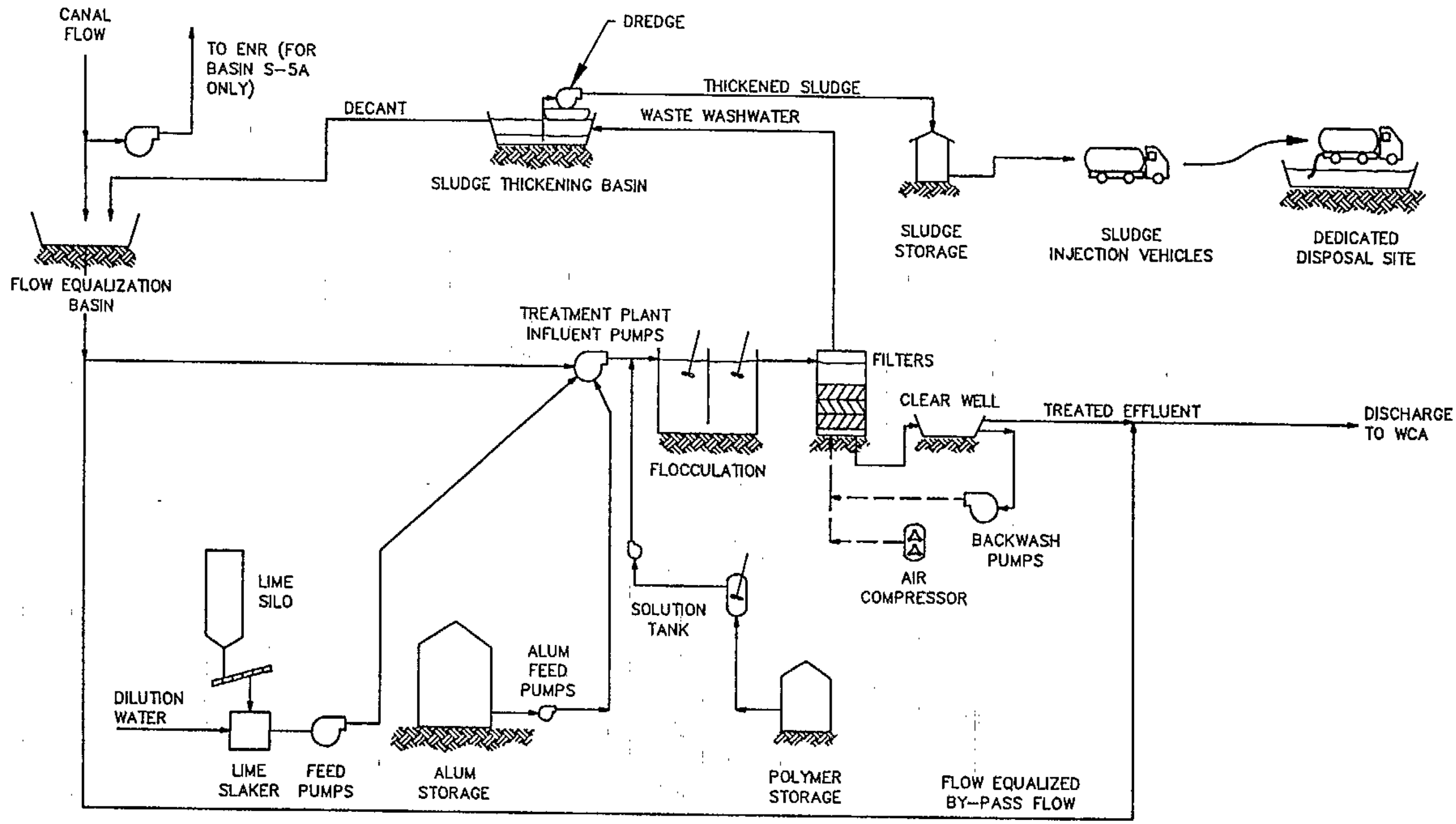

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Figure 3-2
Direct Filtration Flowsheet

05-12-93 BernieA FIGURE1

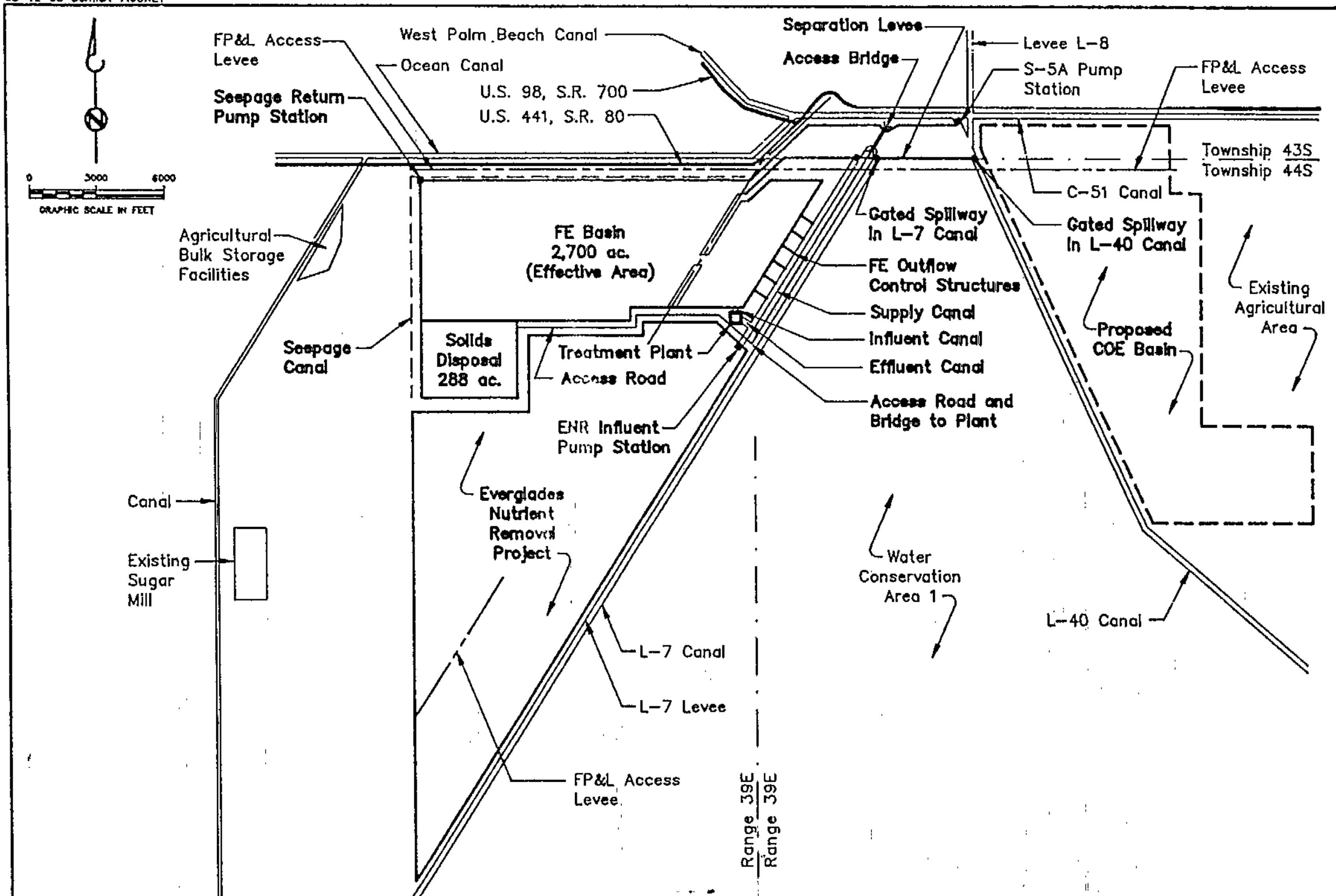

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Figure 3-3
Flow Equalization / Direct Filtration at Basin S-5A

05-12-93 BernieA E:\7518\FIGURE2

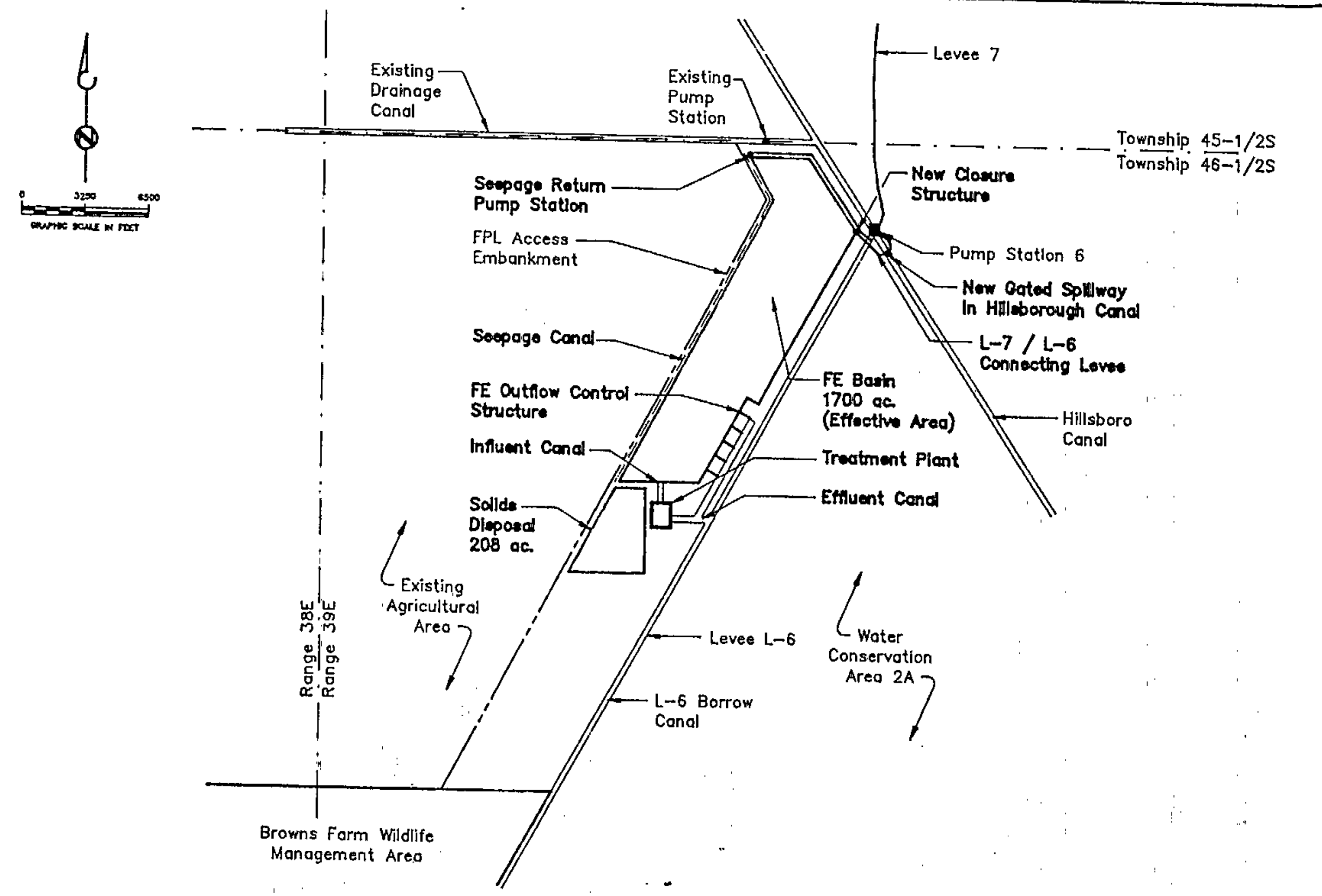

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Figure 3-4
Flow Equalization / Direct Filtration at Basin S-6

05-12-93 BernieA E:\7518\FIGURE3

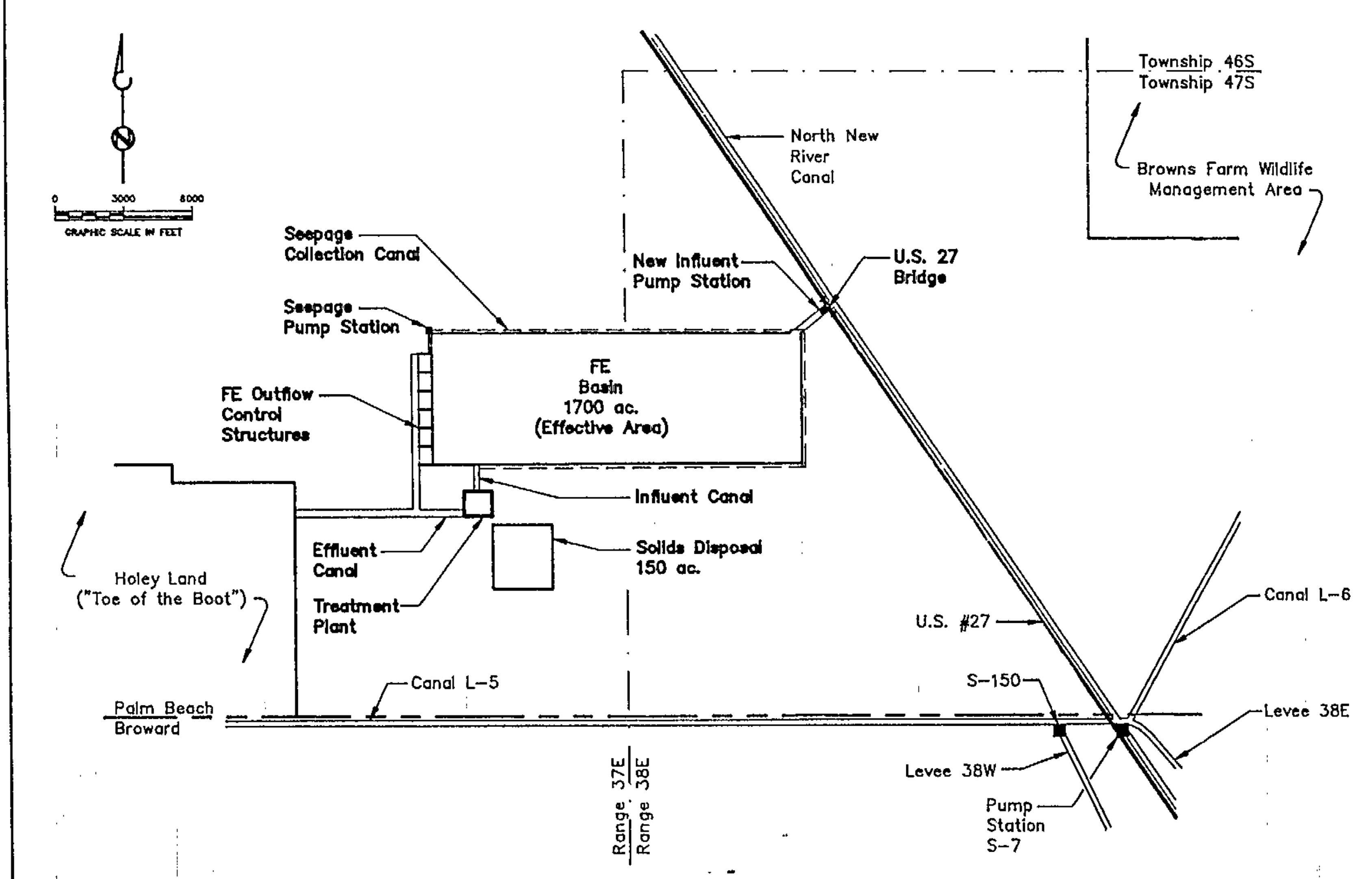

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Figure 3–5
Flow Equalization / Direct Filtration
at Basin S–7

05-12-93 BemisA E:\7518\FIGURE4

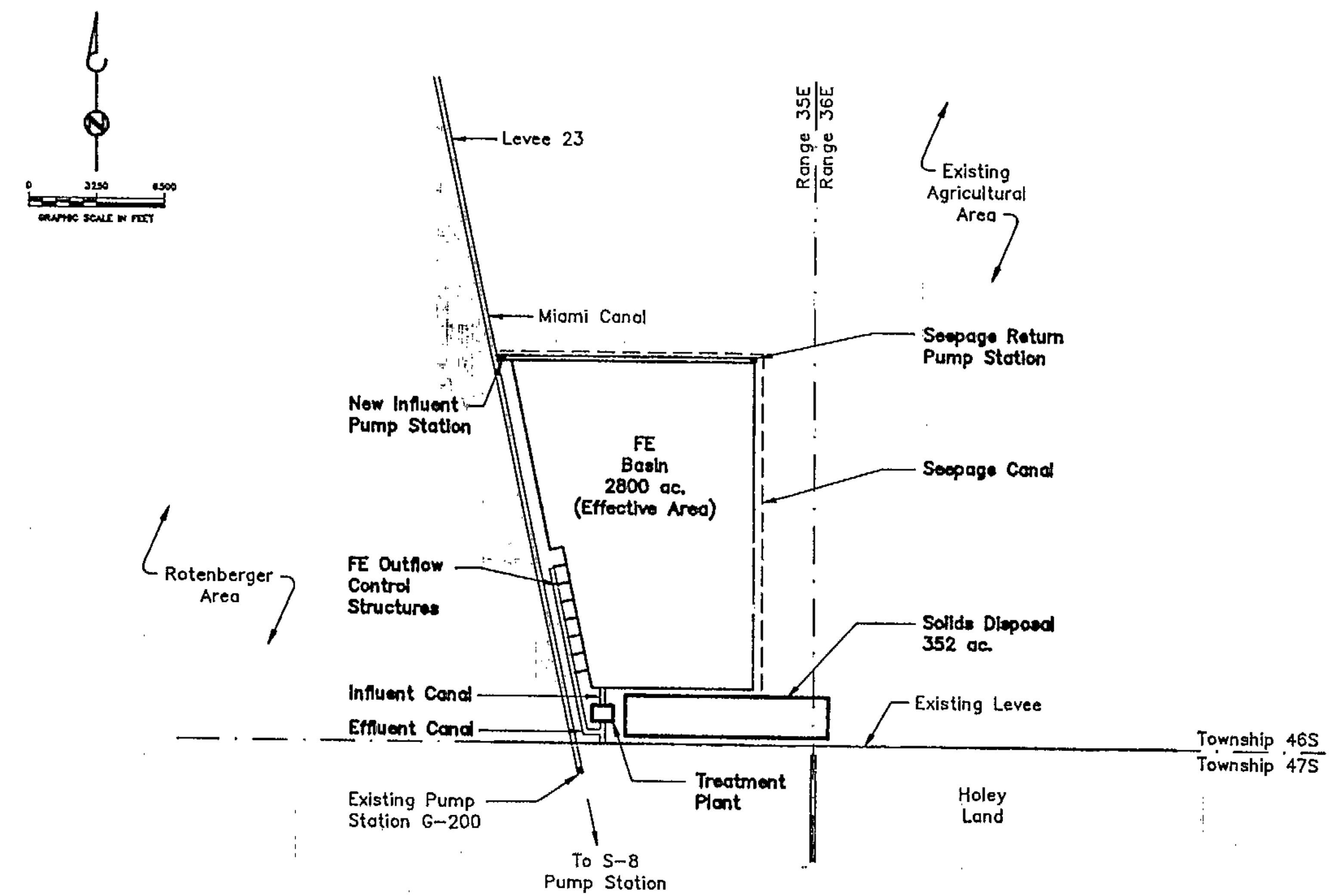

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Figure 3-6
Flow Equalization / Direct Filtration at Basin S-8

APPENDIX A-3

Basin No.: 5

Plant capacity,	MGD:	200
	ac-ft:	613
FE basin surface area	acres:	2700
FE basin volume,	MG:	7038
	ac-ft:	21599
FE Basin water depth max,	ft:	8
ENR daily flow avg,	MGD:	93
	ac-ft:	285
ENR daily flow max,	MGD:	395
	ac-ft:	1212
Total influent P load,	lbs:	1038492
	kgs:	471056
Total influent flow,	MG:	697122
	ac-ft:	2139249

Maximum daily flow, MG: 3007
Maximum daily P-load, lbs: 7665.37

Plant Effluent

P load,	lbs:	25388
	kgs:	11516
Conc,	mg/l:	.0099
Flow,	MG:	304423
	ac-ft:	934178
Percent of flow:		43.66851
Percent P WCAs :		8.782689

By-pass

P load,	lbs:	101376
	kgs:	45983
Conc,	mg/l:	.2086
Flow,	MG:	58268
	ac-ft:	178807
Percent of flow:		8.358412
Percent P WCAs :		35.06924

ENR Effluent

P load,	lbs:	162309
	kgs:	73623
Conc,	mg/l:	.0587
Flow,	MG:	331263
	ac-ft:	1016544
Percent of flow:		47.51873
Percent P WCAs :		56.14807

P Load to ENR, lbs: 471830
kgs: 214020

Discharge to WCAs (Blend)

Percent of P removed :		72.16406
---->Concentration,	mg/l:	.0499
Flow,	MG:	693954
	ac-ft:	2129527
P Load,	lbs:	289074
	kgs:	131123

```
      Percent of flow        :  99.54553
      Mean flow (all days),        MG:  195
                               ac-ft:  600
      Mean flow (+ve flow days), MG:  642
                               ac-ft:  1971
      Mass allowed,               lbs:  291750
                                  kgs:  132336

Remaining stored volume in basin, MG:   3168
                                 ac-ft:  9722
Percent of flow                       :  .4544647
P load in FE basin,               lbs:  5512

 Total no. zero flow days     2476   Percent of days         69.53103
 Total no. +ve flow days      1085  Percent of days          30.46897
 Total no. bypass days        88  Percent +ve flow days     8.1106

 No. of days flow > design    832  Percent of days          23.36422
 No. of days flow < design    2729  Percent of days         76.63577
 No. of +ve days < design     253 Percent of days           23.31797

No. of days operating @ capacity 1468     % of time 41.22438
No. of days operating < capacity 122      % of time 3.426004
No. of days in operation          1590     % of time 44.65038
```

Basin No.: 6

Plant capacity,	MGD:	150
	ac-ft:	460
FE basin surface area	acres:	1700
FE basin volume,	MG:	4431
	ac-ft:	13600
FE Basin water depth max,	ft:	8
Total influent P load,	lbs:	421758
	kgs:	191308
Total influent flow,	MG:	401863
	ac-ft:	1233192

Maximum daily flow, MG: 1639
Maximum daily P-load, lbs: 6826.119

Plant Effluent
P load, lbs: 23545
kgs: 10680
Conc, mg/l: .0099
Flow, MG: 282327
ac-ft: 866375
Percent of flow: 70.2547
Percent P WCAs : 14.32549

By-pass
P load, lbs: 140818
kgs: 63874
Conc, mg/l: .1422
Flow, MG: 118661
ac-ft: 364134
Percent of flow: 29.52776
Percent P WCAs : 85.67451

Discharge to WCAs (Blend)
Percent of P removed : 61.0289
---->Concentration, mg/l: .0491
Flow, MG: 400991

ac-ft: 1230515
P Load, lbs: 164363
kgs: 74555
Percent of flow : 99.78295
Mean flow (all days), MG: 112
ac-ft: 346
Mean flow (+ve flow days), MG: 456
ac-ft: 1398
Mass allowed, lbs: 167577
kgs: 76012

Remaining stored volume in basin, MG: 872
ac-ft: 2676
Percent of flow : .2170472
P load in FE basin, lbs: 1035

Total no. zero flow days	2679	Percent of days	75.23167
Total no. +ve flow days	882	Percent of days	24.76832
Total no. bypass days	248	Percent +ve flow days	28.11791
No. of days flow > design	710	Percent of days	19.93822
No. of days flow < design	2851	Percent of days	80.06178
No. of +ve days < design	172	Percent of days	19.50113
No. of days operating @ capacity	1814	% of time	50.94075
No. of days operating < capacity	146	% of time	4.099972
No. of days in operation	1960	% of time	55.04072

Basin No.: 7

Plant capacity,	MGD:	130
	ac-ft:	398
FE basin surface area	acres:	1400
FE basin volume,	MG:	3649
	ac-ft:	11200
FE Basin water depth max,	ft:	8
Total influent P load,	lbs:	400891
	kgs:	181842
Total influent flow,	MG:	574704
	ac-ft:	1763587

Maximum daily flow, MG: 1785
Maximum daily P-load, lbs: 3414.619

Plant Effluent
- P load, lbs: 25935
- kgs: 11764
- Conc, mg/l: .0099
- Flow, MG: 310984
- ac-ft: 954313
- Percent of flow: 54.11203
- Percent P WCAs : 10.91246

By-pass
- P load, lbs: 211732
- kgs: 96041
- Conc, mg/l: .0968
- Flow, MG: 262234
- ac-ft: 804714
- Percent of flow: 45.62939
- Percent P WCAs : 89.08754

Discharge to WCAs (Blend)
- Percent of P removed : 40.71514
- ---->Concentration, mg/l: .0497
- Flow, MG: 573214
- ac-ft: 1759015
- P Load, lbs: 237667
- kgs: 107805
- Percent of flow : 99.74075
- Mean flow (all days), MG: 161
- ac-ft: 495
- Mean flow (+ve flow days), MG: 376
- ac-ft: 1155
- Mass allowed, lbs: 240297
- kgs: 108997

Remaining stored volume in basin, MG: 1489
ac-ft: 4572
Percent of flow : .2592489
P load in FE basin, lbs: 1202

Total no. zero flow days	2035	Percent of days	57.14687
Total no. +ve flow days	1526	Percent of days	42.85313
Total no. bypass days	567	Percent +ve flow days	37.15596
No. of days flow > design	1036	Percent of days	29.09295
No. of days flow < design	2525	Percent of days	70.90705
No. of +ve days < design	490	Percent of days	32.11009
No. of days operating @ capacity	2320	% of time	65.15024
No. of days operating < capacity	210	% of time	5.89722
No. of days in operation	2530	% of time	71.04745

Basin No.: 8

Plant capacity,	MGD:	340
	ac-ft:	1043

FE basin surface area	acres:	2400
FE basin volume,	MG:	6256
	ac-ft:	19199
FE Basin water depth max,	ft:	8

Total Influent P load,	lbs:	794870
	kgs:	360550
Total influent flow,	MG:	661411
	ac-ft:	2029664

Maximum daily flow, MG: 1992
Maximum daily P-load, lbs: 8563.133

Plant Effluent
- P load, lbs: 44038
- kgs: 19975
- Conc, mg/l: .0099
- Flow, MG: 528041
- ac-ft: 1620394
- Percent of flow: 79.83557
- Percent P WCAs : 16.04216

By-pass
- P load, lbs: 230477
- kgs: 104543
- Conc, mg/l: .2076
- Flow, MG: 133072
- ac-ft: 408356
- Percent of flow: 20.11942
- Percent P WCAs : 83.95784

Discharge to WCAs (Blend)
- Percent of P removed : 65.46405
- ---->Concentration, mg/l: .0497
- Flow, MG: 661113
- ac-ft: 2028750
- P Load, lbs: 274515
- kgs: 124519
- Percent of flow : 99.95499
- Mean flow (all days), MG: 185
- ac-ft: 569
- Mean flow (+ve flow days), MG: 411
- ac-ft: 1263
- Mass allowed, lbs: 276548
- kgs: 125441

Remaining stored volume in basin, MG: 297
ac-ft: 913
Percent of flow : 4.501508E-02
P load in FE basin, lbs: 515

Total no. zero flow days	1954	Percent of days	54.87223
Total no. +ve flow days	1607	Percent of days	45.12777

Total no. bypass days	247	Percent +ve flow days	15.37026
No. of days flow > design	698	Percent of days	19.60124
No. of days flow < design	2863	Percent of days	80.39877
No. of +ve days < design	909	Percent of days	56.56503

No. of days operating @ capacity	1381	% of time 38.78124
No. of days operating < capacity	494	% of time 13.87251
No. of days in operation	1875	% of time 52.65375

TECHNICAL MEMORANDUM NO. 4 22-7518-01

April 30, 1993

TO: FILE

FROM: RICHARD J. JUNNIER

SUBJECT: CAPITAL, O&M, AND 20-YEAR PRESENT WORTH COST ESTIMATES

Capital Cost Estimates

Tables 4-1 and 4-2 summarize capital costs for the flow equalization/direct filtration treatment plants for each of the basins. Capital costs presented in Table 4-1 are based on an assumption of 35 percent reduction in TSS and particulate P in the flow equalization basin, whereas Table 4-2 capital costs are based an assumption of zero reduction in TSS and particulate P in the flow equalization basin. Capital costs for the direct filtration plants were estimated with BACPAC, Brown and Caldwell's computerized cost estimating and scheduling program. Costs are expressed in June 1993 dollars, for construction projects in South Florida.

Whenever possible, capital costs for the flow equalization basins were developed using components of Burns and McDonnell's (B&M) Stormwater Treatment Areas (STA) and their corresponding unit costs (B&M, Conceptual Design of Stormwater Treatment Areas, March 31, 1992). STA cost components were used based on the assumption that a flow equalization basin is essentially an STA without some of the flow control structures and other components (i.e., wetland vegetation). A detailed cost breakdown is only provided for costs based on an assumption of 35 percent reduction in TSS and particulate P in the flow equalization basin. These can be found in Appendices A-4 and B-4.

Flow equalization basin capital costs vary by basin size, flow control configurations and other unit costs (land acquisition, for example). Treatment plant capital cost differences are due primarily to differences in the number of filters required for treatment. Table 4-1 shows that the filtration rate can significantly affect capital costs.

Cost contingency assumptions were made to be in agreement with those assumed by B&M so that a meaningful comparison of costs could be performed in the plan formulation phase. Cost contingencies for engineering, design and construction management were assumed to be 15 percent; construction contingencies were assumed to be 20 percent; contingencies for land acquisition were assumed to be 10 percent per discussion with B&M. Costs were shown inflated to June, 1993 dollars in order to provide the most pertinent cost estimates for the plan formulation phase of the Everglades Protection Project.

Table 4.1
Estimated Capital Costs for Flow Equalization Basin/Direct Filtration (a)

Item	Basin 5A		Basin 6		Basin 7		Basin 8		Totals	
	High Rate	Low Rate	High Rate	Low Rate	High Rate	Low Rate	High Rate	Low Rate	High Rate	Low Rate
Treatment Plant Size (MGD) (b)	200	200	150	150	130	130	340	340	--	--
Flow Equalization Basin Size (acres) (b)	2,700	2,700	1,700	1,700	1,400	1,400	2,400	2,400	--	--
Treatment Plant Capital Cost (a)	$36,719	$40,526	$29,671	$35,269	$28,998	$32,688	$46,965	$58,731	$142,352	$167,214
Flow Equalization Basin Capital Cost (a)	$46,511	$46,511	$22,695	$22,695	$33,027	$33,027	$44,862	$44,862	$147,096	$147,096
Total Capital Cost (a)	$83,230	$87,037	$52,366	$57,964	$62,025	$65,715	$91,828	$103,594	$289,448	$314,310

(a) Thousands of June 1993 dollars.
(b) Based on an assumed 35 percent reduction in TSS and particulate P in the flow equalization basin.

Table 4.2
Estimated Capital Costs for Flow Equalization Basin/Direct Filtration (a)

Item	Basin 5A		Basin 6		Basin 7		Basin 8		Totals	
	High Rate	Low Rate	High Rate	Low Rate	High Rate	Low Rate	High Rate	Low Rate	High Rate	Low Rate
Treatment Plant Size (MGD) (b)	260	260	190	190	190	190	450	450	--	--
Flow Equalization Basin Size (acres) (b)	2,800	2,800	1,700	1,700	1,700	1,700	2,800	2,800	--	--
Treatment Plant Capital Cost (a)	$43,978	$48,435	$35,192	$41,644	$37,412	$42,046	$56,567	$70,488	$173,150	$202,613
Flow Equalization Basin Capital Cost (a)	$47,537	$47,537	$22,695	$22,695	$37,108	$37,108	$49,209	$49,209	$156,549	$156,549
Total Capital Cost (a)	$91,516	$95,972	$57,887	$64,339	$74,520	$79,154	$105,777	$119,698	$329,699	$359,162

(a) Thousands of June 1993 dollars.
(b) Based on an assumed zero reduction in TSS and particulate P in the flow equalization basin.

Flow Equalization Basin Capital Cost Estimate Assumptions

The following is an example of how the capital costs for the flow equalization basin were derived. A similar cost derivation process was performed for each basin, the details for the cost associated with 35 percent reduction in TSS and particulate P are contained in Appendix C-4.

The following assumptions were made for Basin S-5A:

- Land acquisition cost of $3,500 per acre (Per discussion with District staff, 5/11/93).

- B&M STA-1 influent control structures are used to route basin S-5A flows to the flow equalization basin. This assumption is reasonable since both the STA and the flow equalization basin are be required to handle peak flows. These structures include gated spillway in L-7 canal, L-40 canal, and ENR supply canal, and a cost of $2,333,000, $2,333,000, and $2,958,000, respectively (Per discussion with District staff, 5/11/93). Additional structures include a 1.0 mile separation levee. The cost is $1,074,000 (Per discussion with District staff, 5/11/93).

- 13.2 miles of 11 ft levees with peat excavation depth of 6 ft(B&M Conceptual Design Report, Page III-9) corresponding to a cost of $638,730 per mile (B&M STA Conceptual Design Report, Table III-6) and a total cost of $8,431,236.

- Seepage collection canals have a unit cost of $100,000 per mile and have a 4.50 mile perimeter, resulting in a capital cost of $450,000.

- The 147 cfs seepage return pump station used in the B&M Conceptual Design Report is used for the flow equalization basin seepage return at a total cost of $1,417,310.

- As in Zone 2, STA-1, twenty outflow structures are used to bypass peak flows around the treatment plant after equalization of flows in the basin. This results in a total cost of $900,000 at a unit cost of $45,000 each.

- The Everglades Nutrient Removal (ENR) Project is used as part of the treatment process and needs to be loaded to its hydraulic limit. In order to do this the influent pump station will need to be upgraded from a capacity 600 cfs to 800 cfs. The B&M report upgrades this pump station (and reverses its pumping direction). A cost of $1,700,000 is used to upgrade the influent pump station and $1,200,000 is used to upgrade the outflow pump station.

- The two FP&L embankments are breached three times requiring three FP&L access embankments, resulting in a cost of $2,436,000.

In Basins S-6, S-7 and S-8 many of the previous assumptions hold true, based on the B&M report, such as:

- Levee unit costs for an 11 ft levee (8 ft deep with a 3 ft free board) at the following assumed peat thickness:
  - Basin S-6 6 feet (B&M Conceptual Design Report, Page IV-5)
  - Basin S-7 4 feet (B&M Conceptual Design Report, Page V-6)
  - Basin S-8 4 feet (B&M Conceptual Design Report, Page VI-6)
- Influent control structure configurations per recommended B&M STA alternative.
- Seepage collection and return pump station unit costs.
- Outflow control structure requirements and unit costs.
- Land acquisition costs (B&M STA Conceptual Design Report, Table III-2).
- Location of flow equalization basins are in close proximity to proposed STAs.

The listed assumptions are considered reasonable since both the STAs and flow equalization basins will receive all flows from the basin and will thus require similar components.

Operations and Maintenance Costs

Table 4-3 summarizes O&M costs for the direct filtration treatment plants, based on an assumption of 35 percent reduction in TSS and particulate P in the flow equalization basin. O&M costs are broken down by treatment unit in spreadsheets contained in Appendix C-4. Appendix C-4 also contains a listing of assumptions used in deriving O&M costs.

Table 4-3
Estimated Annual Operating and Maintenance Costs for Flow Equalization/Direct Filtration

Item	O&M cost, thousands dollars per year[a]							
	Basin S-5A		Basin S-6		Basin S-7		Basin S-8	
	High Rate	Low Rate	High Rate	Low Rate	High Rate	Low Rate	High Rate	Low Rate
Labor[b]	$487	$582	$445	$535	$468	$585	$721	$921
Materials[b]	107	115	96	105	101	116	139	159
Chemicals	1,772	1,772	1,471	1,471	1,400	1,400	2,369	2,369
Energy	298	298	272	272	301	301	486	486
Monitoring	105	105	105	105	105	105	105	105
Total	$2,769	$2,872	$2,390	$2,489	$2,377	$2,508	$3,821	$4,041

a Thousands of June 1993 dollars.
b Does not include labor and materials for monitoring; these costs are included separately under "monitoring."

High-rate filtration plants have lower O&M costs than low-rate filtration plants because they have fewer filters, hence fewer operators. Note that O&M labor is assigned to treatment units only when the units are operating. For example, Basin S-5A filters are operated only 45 percent of the time, although, historically, flows occur only one-third of the time. Therefore, labor costs assigned to the filters are 45 percent of the amount that would be assigned if the filters were operated full time. It is assumed that the District will find other productive work for treatment plant personnel when the treatment plants are not operating.

20-Year Present Worth Costs

Present worth costs are calculated by:

$$PW = CC + f\,(O\&M) \qquad (2\text{-}13)$$

where:

PW = present worth in present dollars
CC = capital cost in present dollars
f = O&M cost factor
O&M = O&M costs in current dollars

The O&M cost factor f is 9.8181, based on a 20-year period and an 8 percent discount rate. The estimated present worth costs for the direct filtration technology are:

Table 4-4
[illegible] Present Worth Cost for
[illegible] Direct Filtration[a]

Location	High Rate	Low Rate
Basin S-5A	$110,423	$115,236
Basin S-6	75,829	82,401
Basin S-7	85,360	90,338
Basin S-[illegible]	129,[illegible]	143,269
Totals	$400,954	$431,243
$/Pound of P Removed	109	116

[a] Thousands of June 1993 dollars.

Table 4-4 also shows the cost of phosphorus removal, expressed in dollars per pound of phosphorus removed and total present worth cost. This cost is obtained by dividing the present worth by the mass of phosphorus removed over the 20-year period.

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APPENDIX A-4

Basin S-5A Capital Costs - Flow Equalization Basin

	Estimated Quantity	Unit Cost	Unit	Amount
Land Acquisition	2,970	3,500	$/acre	$10,395,000
Gated Spillway in L-7 Canal (2,400 cfs)	1	2,333,000	L.S.	2,333,000
Seperation Levee WCA-1	1	1,074,000	L.S.	1,074,000
Gated Spillway in L-40 Canal (2,400 cfs)	1	2,333,000	L.S.	2,333,000
Control Structure in ENR Supply Canal	1	2,958,000	L.S.	2,958,000
Supply Canal Bridge	1	635,556	L.S.	635,556
Perimeter Levee (height= 11 ft, peat depth= 6 ft)	13.20	638,730	$/mi	8,431,236
FE Outflow Control Structures	20	45,000	Each	900,000
Seepage Collection Canal	4.50	100,000	$/mi	450,000
Seepage Return Pump Station (147 cfs capacity)	1	1,417,310	L.S.	1,417,310
FP&L Access Embankment	3	812,000	L.S.	2,436,000
Everglades Nutrient Removal Project				
Inflow Pump Station Upgrade	1	1,700,000	L.S.	1,700,000
Outflow Pump Station Upgrade	1	1,200,000	L.S.	1,200,000
Subtotal				$35,063,102
Contingencies				
Engineering, Design, and C.M.			15%	3,880,215
Land Acquisition			10%	1,039,500
Construction			20%	5,173,620
Total FE Basin/ENR Pump Station Capital Cost				$45,156,437
Inflation of 3% from August 1992 to June 1993				$46,511,130

Basin S-6 Capital Costs - Flow Equalization Basin

	Estimated Quantity	Unit Cost	Unit	Amount
Land Acquisition	1,870	3,000	$/acre	$5,610,000
Perimeter Levee (height=11 ft, peat depth=6 ft)	6.17	638,730	$/mi	3,940,964
Distribution Canal Exterior Levee (height=9 ft, peat depth=6 ft)	1.98	458,000	$/mi	906,840
L-7/L-6 Connecting Levee	1	800,000	L.S.	800,000
Perimeter Seepage Collection Canal	4.30	100,000	$/mi	430,000
FE Outflow Control Structures	10	45,000	Each	450,000
Seepage Return Pump Station (153 cfs capacity)	1	1,436,400	L.S.	1,436,400
Gated Spillway in Hillsboro Canal (2,925 cfs capacity)	1	2,522,800	L.S.	2,522,800
Power Line to Seepage Pump Station	1.24	30,000	$/mi	37,199
Power Line to Treatment Plant	2.50	30,000	$/mi	75,000
Supply Canal Closure Structure (2,925 cfs capacity)	1	320,000	L.S.	320,000
Subtotal				$16,529,203
Contingencies				
Engineering, Design, and C.M.			15%	1,637,880
Land Acquisition			10%	561,000
Construction			20%	3,305,841
Total FE Basin Capital Cost				$22,033,924
Inflation of 3% from August 1992 to June 1993				$22,694,942

Basin S-7 Capital Costs - Flow Equalization Basin

	Estimated Quantity	Unit Cost	Unit	Amount
Land Acquisition	1,540	2,000	$/acre	$3,080,000
Perimeter Levee (height=11 ft, peat depth=4 ft)	8.00	560,080	$/mi	4,480,640
Supply Canal and Levees (height=9 ft, peat depth=4 ft)	0.56	810,000	$/mi	453,600
FE Outflow Control Structures	15	45,000	Each	675,000
New Inflow Pump Station (2,490 cfs)	1	8,516,000	L.S.	8,516,000
New Gated Spillway in North New River Canal (2,800 cfs)	1	2,459,100	L.S.	2,459,100
US-27 Bridges; 2 ea. @ 200' x 44'	17,600	65	Sq.Ft.	1,144,000
US-27 Temporary Construction	5,000	200	Lin.Ft.	1,000,000
Perimeter Seepage Collection Canal	7.20	100,000	$/mi	720,000
Seepage Return Pump Station (206 cfs capacity)	1	1,604,900	L.S.	1,604,900
Power Line to Treatment Plant	2.90	30,000	$/mi	87,000
Power Line to Seepage Pump Station	3.41	30,000	$/mi	102,273
Subtotal				$24,322,513
Contingencies				
Engineering, Design, and C.M.			15%	3,186,377
Land Acquisition			10%	308,000
Construction			20%	4,248,503
Total FE Basin Capital Cost				$32,065,392
Inflation of 3% from August 1992 to June 1993				$33,027,354

Basin S-8 Capital Costs - Flow Equalization Basin

	Estimated Quantity	Unit Cost	Unit	Amount
Land Acquisition	2,640	2,750	$/acre	$7,260,000
Perimeter Levee (height=11 ft, peat depth=4 ft)	9.20	560,080	$/mi	5,152,736
New Inflow Pump Station (4170 cfs)	1	14,206,400	L.S.	14,206,400
L-23 Improvements	2.1	250,000	L.S.	250,000
Distribution Canal Exterior Levee (height=9 ft, peat depth=6 ft)	2.52	405,000	$/mi	1,020,600
Supply Canal and Levees (height=9 ft, peat depth=4 ft)	2.52	810,000	$/mi	2,041,200
FE Outflow Control Structures	18	45,000	Each	810,000
Perimeter Seepage Collection Canal	5.50	100,000	$/mi	550,000
Seepage Return Pump Station (206 cfs capacity)	1	1,604,900	L.S.	1,604,900
L-23 Bridges; 1 ea. @ 180' x 28'	5,040	65	Sq.Ft.	327,600
Holey Land Levee Bridge	4,750	65	Sq.Ft.	308,750
Power Line to Seepage Pump Station	2.52	30,000	$/mi	75,614
Subtotal				$33,607,800
Contingencies				
Engineering, Design, and C.M.			15%	3,952,170
Land Acquisition			10%	726,000
Construction			20%	5,269,560
Total FE Basin Capital Cost				$43,555,530
Inflation of 3% from August 1992 to June 1993				$44,862,195

APPENDIX B-4

High Rate Direct Filtration Treatment Plant with Flow Equalization

Basin S-5A Capital Costs

Process Area	Total
Contractor Indirects	$835,000
Land Acquisition	877,500
Influent Channel	730,000
Yard Development	416,000
Influent Pump Station	3,890,000
Water Feed Channel	872,000
Flocculation	2,355,000
Filters	8,012,000
Chemical Addition	1,026,000
Backwash System	830,000
Reclamation Basin/Thickener	728,000
Nurse Tanks	102,000
Dedicated Land Disposal	1,008,000
Effluent Channel	456,000
Yard Piping	1,148,000
Electrical/Instruments	3,130,000
Central Plant Building	675,000
Subtotal	$27,090,500
Bond @ 1%	270,905
Subtotal	$27,361,405
Engineering @ 15%	3,972,586
Land Acquisition @ 10%	87,750
Construction @ 20%	5,296,781
Total Treatment Plant Capital Cost	$36,718,522

High Rate Direct Filtration Treatment Plant with Flow Equalization

Basin S-6 Capital Costs

Process Area	Total
Contractor Indirects	$691,000
Land Acquisition	505,250
Influent Channel	326,000
Yard Development	310,000
Influent Pump Station	3,430,000
Water Feed Channel	872,000
Flocculation	2,155,000
Filters	5,832,000
Chemical Addition	754,000
Backwash System	830,000
Reclamation Basin/Thickener	686,000
Nurse Tanks	102,000
Dedicated Land Disposal	624,000
Effluent Channel	521,000
Yard Piping	950,000
Electrical/Instruments	2,590,000
Central Plant Building	675,000
Subtotal	$21,853,250
Bond @ 1%	218,533
Subtotal	$22,071,783
Engineering @ 15%	3,234,980
Land Acquisition @ 10%	50,525
Construction @ 20%	4,313,307
Total Treatment Plant Capital Cost	$29,670,594

High Rate Direct Filtration Treatment Plant with Flow Equalization

Basin S-7 Capital Costs

Process Area	Total
Contractor Indirects	$686,000
Land Acquisition	345,450
Influent Channel	185,000
Yard Development	268,000
Influent Pump Station	3,430,000
Water Feed Channel	872,000
Flocculation	2,061,000
Filters	5,832,000
Chemical Addition	565,000
Backwash System	830,000
Reclamation Basin/Thickener	744,000
Nurse Tanks	60,000
Dedicated Land Disposal	300,000
Effluent Channel	962,000
Yard Piping	943,000
Electrical/Instruments	2,572,000
Central Plant Building	675,000
Subtotal	$21,330,450
Bond @ 1%	213,305
Subtotal	$21,543,755
Engineering @ 15%	3,179,746
Land Acquisition @ 10%	34,545
Construction @ 20%	4,239,661
Total Treatment Plant Capital Cost	$28,997,706

High Rate Direct Filtration Treatment Plant with Flow Equalization

Basin S-8 Capital Costs

Process Area	Total
Contractor Indirects	$1,078,000
Land Acquisition	992,750
Influent Channel	370,000
Yard Development	635,000
Influent Pump Station	5,834,000
Water Feed Channel	872,000
Flocculation	2,908,000
Filters	10,104,000
Chemical Addition	1,319,000
Backwash System	1,660,000
Reclamation Basin/Thickener	812,000
Nurse Tanks	135,000
Dedicated Land Disposal	968,000
Effluent Channel	740,000
Yard Piping	1,482,000
Electrical/Instruments	4,042,000
Central Plant Building	675,000
Subtotal	$34,626,750
Bond @ 1%	346,268
Subtotal	$34,973,018
Engineering @ 15%	5,097,040
Land Acquisition @ 10%	99,275
Construction @ 20%	6,796,054
Total Treatment Plant Capital Cost	$46,965,386

Low Rate Direct Filtration Treatment Plant with Flow Equalization

Basin S-5A Capital Costs

Process Area	Total
Contractor Indirects	$956,000
Land Acquisition	866,250
Influent Channel	730,000
Yard Development	416,000
Influent Pump Station	3,890,000
Water Feed Channel	872,000
Flocculation	2,355,000
Filters	11,051,000
Chemical Addition	1,026,000
Backwash System	830,000
Reclamation Basin/Thickener	728,000
Nurse Tanks	102,000
Dedicated Land Disposal	1,008,000
Effluent Channel	456,000
Yard Piping	1,315,000
Electrical/Instruments	3,585,000
Central Plant Building	675,000
Subtotal	$30,861,250
Bond @ 1%	308,613
Subtotal	$31,169,863
Engineering @ 15%	3,972,586
Land Acquisition @ 10%	86,625
Construction @ 20%	5,296,781
Total Treatment Plant Capital Cost	$40,525,854

Low Rate Direct Filtration Treatment Plant with Flow Equalization

Basin S-6 Capital Costs

Process Area	Total
Contractor Indirects	$823,000
Land Acquisition	498,200
Influent Channel	326,000
Yard Development	310,000
Influent Pump Station	3,430,000
Water Feed Channel	872,000
Flocculation	2,155,000
Filters	9,136,000
Chemical Addition	754,000
Backwash System	830,000
Reclamation Basin/Thickener	686,000
Nurse Tanks	102,000
Dedicated Land Disposal	624,000
Effluent Channel	521,000
Yard Piping	1,131,000
Electrical/Instruments	3,085,000
Central Plant Building	675,000
Subtotal	$25,958,200
Bond @ 1%	259,582
Subtotal	$26,217,782
Engineering @ 15%	3,857,937
Land Acquisition @ 10%	49,820
Construction @ 20%	5,143,916
Total Treatment Plant Capital Cost	$35,269,456

Low Rate Direct Filtration Treatment Plant with Flow Equalization

Basin S-7 Capital Costs

Process Area	Total
Contractor Indirects	$773,000
Land Acquisition	338,400
Influent Channel	185,000
Yard Development	268,000
Influent Pump Station	3,430,000
Water Feed Channel	872,000
Flocculation	2,061,000
Filters	8,010,000
Chemical Addition	565,000
Backwash System	830,000
Reclamation Basin/Thickener	744,000
Nurse Tanks	60,000
Dedicated Land Disposal	300,000
Effluent Channel	962,000
Yard Piping	1,063,000
Electrical/Instruments	2,899,000
Central Plant Building	675,000
Subtotal	$24,035,400
Bond @ 1%	240,354
Subtotal	$24,275,754
Engineering @ 15%	3,590,603
Land Acquisition @ 10%	33,840
Construction @ 20%	4,787,471
Total Treatment Plant Capital Cost	$32,687,668

Low Rate Direct Filtration Treatment Plant with Flow Equalization

Basin S-8 Capital Costs

Process Area	Total
Contractor Indirects	$1,355,000
Land Acquisition	984,500
Influent Channel	370,000
Yard Development	635,000
Influent Pump Station	5,834,000
Water Feed Channel	872,000
Flocculation	2,906,000
Filters	17,042,000
Chemical Addition	1,319,000
Backwash System	1,660,000
Reclamation Basin/Thickener	812,000
Nurse Tanks	135,000
Dedicated Land Disposal	968,000
Effluent Channel	740,000
Yard Piping	1,864,000
Electrical/Instruments	5,083,000
Central Plant Building	675,000
Subtotal	$43,254,500
Bond @ 1%	432,545
Subtotal	$43,687,045
Engineering @ 15%	6,405,382
Land Acquisition @ 10%	98,450
Construction @ 20%	8,540,509
Total Treatment Plant Capital Cost	$58,731,386

APPENDIX C-4

High Rate Direct Filtration Treatment Plant with Flow Equalization

BASIN S-5A OPERATION AND MAINTENANCE COSTS

Operation	Basis For Costs	Total Cost
Feed pumping to FE	Avg. flow 84 mgd, 10 ft TDH	$129,010
FE basin	Capacity 7039 million gallons	44,336
Feed pumping from FE	Average flow 84 mgd, 25 ft TDH	227,990
Chemical delivery		
Alum	Avg. rate = 2561 lb/hr, pure, Note A.	1,428,641
Polymer #1	Avg. rate = 351 lb/day, Note A.	264,512
Polymer #2	Avg. rate = 0 lb/day, Note A.	
CaO	Avg. rate 466 lb/hr, Note A	135,539
Rapid mix	Takes place in feed pump	
Flocculation	Eight tanks, total volume = 266,930 cu ft, G = 40 sec-1, time = 44.6 %.	13,801
Filters (low rate)		
Structures	Fourteen filter beds, 18,144 sq ft total area, 44.6 % time	200,140
Air scour/back-wash	Four min air scour @ 4 cfm/sq ft, six min backwash @ 31 gpm/sq ft., % time = 44.6.	28,005
Clear well	Volume = 250,000 gal.	434
Spent backwash basin/thickener	Area = 4.5 acres, one dredge, operating 11 mos/yr.	53,981
Dedicated land disposal	Area = 220 acres, 2 subsurface sludge injection vehicles operating 11/mos/yr.	82,960
Monitoring	People = 2	105,344
Operations bldg.	Area = 5,000 sq ft, includes offices, laboratory, maintenance.	55,000
Miscellaneous		
Total O & M Cost		$2,769,693

High Rate Direct Filtration Treatment Plant with Flow Equalization

BASIN S-6 OPERATION AND MAINTENANCE COSTS

Operation	Basis For Costs	Total Cost
Feed pumping	Avg. flow 77 mgd, 10	$117,410
to FE	ft TDH	0
		0
FE basin	Capacity 4432 million gallons	27,927
		0
Feed pumping	Average flow 77 mgd, 25 ft	210,790
from FE	TDH	0
		0
Chemical delivery		0
Alum	Avg. rate = 2068 lb/hr, pure, Note A.	1,154,024
Polymer #1	Avg. rate = 323 lb/day, Note A.	244,462
Polymer #2	Avg. rate = 0 lb/day, Note A.	0
CaO	Avg. rate 430 lb/hr, Note A	127,297
		0
Rapid mix	Takes place in feed pump	0
		0
		0
		0
Flocculation	Eight tanks, total volume	14,340
	= 200,000 cu ft, G = 40 sec-1,	0
	time = 55 %.	0
		0
Filters (low rate)		0
Structures	Ten filter beds, 13,000	176,440
	sq ft total area, 55 % time	0
		0
Air scour/back-	Four min air scour @ 4 cfm/sq ft,	26,914
wash	six min backwash @ 31 gpm/sq ft.,	0
	% time = 55.	0
Clear well	Volume = 250,000 gal.	434
		0
Spent backwash	Area = 3.1 acres,	53,830
basin/thickener	one dredge, operating 11 mos/yr.	0
		0
Dedicated land	Area = 208 acres, 2 subsurface	75,604
disposal	sludge injection vehicles	0
	operating 11 mos/yr.	0
		0
Monitoring	People = 2	105,344
		0
Operations bldg.	Area = 5,000 sq ft, includes	55,000
	offices, laboratory, maintenance.	0
		0
Miscellaneous		0
		0
Total O & M Cost		$2,389,816

High Rate Direct Filtration Treatment Plant with Flow Equalization

BASIN S-7 OPERATION AND MAINTENANCE COSTS

Operation	Basis For Costs	Total Cost
Feed pumping to FE	Avg. flow 85 mgd, 10 ft TDH	$129,815
		0
		0
FE basin	Capacity 3650 million gallons	23,036
		0
Feed pumping from FE	Average flow 85 mgd, 25 ft TDH	229,810
		0
		0
		0
Chemical delivery		
Alum	Avg. rate = 1959 lb/hr, pure, Note A.	1,093,131
Polymer #1	Avg. rate = 356 lb/day, Note A.	268,512
Polymer #2	Avg. rate = 0 lb/day, Note A.	0
CaO	Avg. rate 258 lb/hr, Note A	87,652
		0
Rapid mix	Takes place in feed pump	0
		0
		0
		0
Flocculation	Eight tanks, total volume = 171,300 cu ft, G = 40 sec-1 time = 71 %.	13,084
		0
		0
		0
		0
Filters (low rate) Structures	Ten filter beds, 13,000 sq ft total area, 71 % time	227,300
		0
		0
Air scour/back-wash	Four min air scour @ 4 cfm/sq ft, six min backwash @ 31 gpm/sq ft., % time = 71.	34,952
		0
		0
Clear well	Volume = 250,000 gal.	434
		0
Spent backwash basin/thickener	Area = 2.0 acres, one dredge, operating 11 mos/yr.	53,704
		0
		0
Dedicated land disposal	Area = 150 acres, 2 subsurface sludge injection vehicles operating 11 mos/yr.	54,905
		0
		0
		0
Monitoring	People = 2	105,344
		0
Operations bldg.	Area = 5,000 sq ft, includes offices, laboratory, maintenance.	55,000
		0
		0
Miscellaneous		0
		0
Total O & M Cost		$2,376,679

High Rate Direct Filtration Treatment Plant with Flow Equalization

BASIN S-8 OPERATION AND MAINTENANCE COSTS

Operation	Basis For Costs	Total Cost
Feed pumping to FE	Avg. flow 145 mgd, 10 ft TDH	$220,330
		0
		0
FE basin	Capacity 6257 million gallons	39,422
		0
Feed pumping from FE	Average flow 145 mgd, 25 ft TDH	390,920
		0
		0
Chemical delivery		0
Alum	Avg. rate = 3325 lb/hr, pure, Note A.	1,855,667
Polymer #1	Avg. rate = 603 lb/day, Note A.	450,280
Polymer #2	Avg. rate = 0 lb/day, Note A.	0
CaO	Avg. rate 403 lb/hr, Note A	123,230
		0
Rapid mix	Takes place in feed pump	0
		0
		0
		0
Flocculation	Eight tanks, total volume = 392,600 cu ft, G = 40 sec-1, time = 52.6 %.	22,429
		0
		0
		0
Filters (low rate)		0
Structures	Twenty filter beds, 26,000 sq ft total area, 52.6 % time	329,300
		0
		0
Air scour/back-wash	Four min air scour @ 4 cfm/sq ft, six min backwash @ 31 gpm/sq ft., % time = 52.6.	45,668
		0
		0
Clear well	Volume = 250,000 gal.	434
		0
Spent backwash basin/thickener	Area = 5.9 acres, one dredge, operating 11 mos/yr.	55,280
		0
		0
Dedicated land disposal	Area = 353 acres, 3 subsurface sludge injection vehicles operating 11 mos/yr.	127,700
		0
		0
		0
Monitoring	People = 2	105,344
		0
Operations bldg.	Area = 5,000 sq ft, includes offices, laboratory, maintenance.	55,000
		0
		0
Miscellaneous		0
		0
Total O & M Cost		$3,821,004

Low Rate Direct Filtration Treatment Plant with Flow Equalization

BASIN S-5A OPERATION AND MAINTENANCE COSTS

Operation	Basis For Costs	Total Cost
Feed pumping to FE	Avg. flow 84 mgd, 10 ft TDH	$129,010
FE basin	Capacity 7039 million gallons	44,336
Feed pumping from FE	Average flow 84 mgd, 25 ft TDH	227,990
Chemical delivery		
Alum	Avg. rate = 2561 lb/hr, pure, Note A.	1,428,641
Polymer #1	Avg. rate = 351 lb/day, Note A.	264,512
Polymer #2	Avg. rate = 0 lb/day, Note A.	
CaO	Avg. rate 466 lb/hr, Note A	135,539
Rapid mix	Takes place in feed pump	
Flocculation	Eight tanks, total volume = 266,930 cu ft, G = 40 sec-1, time = 44.6 %.	13,801
Filters (low rate) Structures	Twenty-two filter beds, 28,500 sq ft total area, 44.6 % time	302,640
Air scour/back-wash	Four min air scour @ 4 cfm/sq ft, six min backwash @ 31 gpm/sq ft., % time = 44.6.	28,005
Clear well	Volume = 250,000 gal.	434
Spent backwash basin/thickener	Area = 4.5 acres, one dredge, operating 11 mos/yr.	53,981
Dedicated land disposal	Area = 220 acres, 2 subsurface sludge injection vehicles operating 11/mos/yr.	82,960
Monitoring	People = 2	105,344
Operations bldg.	Area = 5,000 sq ft, includes offices, laboratory, maintenance.	55,000
Miscellaneous		
Total O & M Cost		$2,872,193

Low Rate Direct Filtration Treatment Plant with Flow Equalization

BASIN S-6 OPERATION AND MAINTENANCE COSTS

Operation	Basis For Costs	Total Cost
Feed pumping to FE	Avg. flow 77 mgd, 10 ft TDH	$117,410
FE basin	Capacity 4432 million gallons	27,927
Feed pumping from FE	Average flow 77 mgd, 25 ft TDH	210,790
Chemical delivery		
Alum	Avg. rate = 2068 lb/hr, pure, Note A.	1,154,024
Polymer #1	Avg. rate = 323 lb/day, Note A.	244,462
Polymer #2	Avg. rate = 0 lb/day, Note A.	
CaO	Avg. rate 430 lb/hr, Note A	127,297
Rapid mix	Takes place in feed pump	
Flocculation	Eight tanks, total volume = 200,000 cu ft, G = 40 sec-1, time = 55 %.	14,340
Filters (low rate)		
Structures	Sixteen filter beds, 20,700 sq ft total area, 55 % time	275,530
Air scour/back-wash	Four min air scour @ 4 cfm/sq ft, six min backwash @ 31 gpm/sq ft., % time = 55.	26,914
Clear well	Volume = 250,000 gal.	434
Spent backwash basin/thickener	Area = 3.1 acres, one dredge, operating 11 mos/yr.	53,830
Dedicated land disposal	Area = 208 acres, 2 subsurface sludge injection vehicles operating 11 mos/yr.	75,604
Monitoring	People = 2	105,344
Operations bldg.	Area = 5,000 sq ft, includes offices, laboratory, maintenance.	55,000
Miscellaneous		
Total O & M Cost		$2,488,906

Low Rate Direct Filtration Treatment Plant with Flow Equalization

BASIN S-7 OPERATION AND MAINTENANCE COSTS

Operation	Basis For Costs	Total Cost
Feed pumping to FE	Avg. flow 85 mgd, 10 ft TDH	$129,815
FE basin	Capacity 3650 million gallons	23,036
Feed pumping from FE	Average flow 85 mgd, 25 ft TDH	229,810
Chemical delivery		
Alum	Avg. rate = 1959 lb/hr, pure, Note A.	1,093,131
Polymer #1	Avg. rate = 356 lb/day, Note A.	268,512
Polymer #2	Avg. rate = 0 lb/day, Note A.	
CaO	Avg. rate 258 lb/hr, Note A	87,652
Rapid mix	Takes place in feed pump	
Flocculation	Eight tanks; total volume = 171,300 cu ft, G = 40 sec-1 time = 71 %.	13,084
Filters (low rate)		
Structures	Fourteen filter beds, 22,000 sq ft total area, 71 % time	358,500
Air scour/back-wash	Four min air scour @ 4 cfm/sq ft, six min backwash @ 31 gpm/sq ft., % time = 71.	34,952
Clear well	Volume = 250,000 gal.	434
Spent backwash basin/thickener	Area = 2.0 acres, one dredge, operating 11 mos/yr.	53,704
Dedicated land disposal	Area = 150 acres, 2 subsurface sludge injection vehicles operating 11 mos/yr.	54,905
Monitoring	People = 2	105,344
Operations bldg.	Area = 5,000 sq ft, includes offices, laboratory, maintenance.	55,000
Miscellaneous		
Total O & M Cost		$2,507,879

Low Rate Direct Filtration Treatment Plant with Flow Equalization

BASIN S-8 OPERATION AND MAINTENANCE COSTS

Operation	Basis For Costs	Total Cost
Feed pumping to FE	Avg. flow 145 mgd, 10 ft TDH	$220,330
FE basin	Capacity 6257 million gallons	39,422
Feed pumping from FE	Average flow 145 mgd, 25 ft TDH	390,920
Chemical delivery		
Alum	Avg. rate = 3325 lb/hr, pure, Note A.	1,855,667
Polymer #1	Avg. rate = 603 lb/day, Note A.	450,280
Polymer #2	Avg. rate = 0 lb/day, Note A.	
CaO	Avg. rate 403 lb/hr, Note A	123,230
Rapid mix	Takes place in feed pump	
Flocculation	Eight tanks, total volume = 392,600 cu ft, G = 40 sec-1, time = 52.6 %.	22,429
Filters (low rate)		
Structures	Thirty-four filter beds, 44,000 sq ft total area, 52.6 % time	549,300
Air scour/back-wash	Four min air scour @ 4 cfm/sq ft, six min backwash @ 31 gpm/sq ft., % time = 52.6.	45,668
Clear well	Volume = 250,000 gal.	434
Spent backwash basin/thickener	Area = 5.9 acres, one dredge, operating 11 mos/yr.	55,280
Dedicated land disposal	Area = 353 acres, 3 subsurface sludge injection vehicles operating 11 mos/yr.	127,700
Monitoring	People = 2	105,344
Operations bldg.	Area = 5,000 sq ft, includes offices, laboratory, maintenance.	55,000
Miscellaneous		
Total O & M Cost		$4,041,004

APPENDIX A-5

TABLE 9: O & M COSTS-S-7, CHEM. SED. W/EARTH BASINS   CHMSEDEB.WK3

OPERATION	BASIS FOR COSTS	Power kwh/yr	Power Dollars	Chemicals tons/yr	Chemicals Dollars	O&M labor hrs/yr	O&M labor Dollars	Admin. & support, Dollars	Maint. matl., Dollars	Fuel, gal/yr	Fuel, Dollars	Total dollars
Feed pumping	Avg. flow 101 mgd, 10		0			2600	46800	14040	15000	112000	78400	154240
to FE	ft TDH		0				0	0			0	0
			0				0	0			0	0
FE basin	Capacity 3900 million gallons		0			540	9720	2916	10400		0	23036
			0				0	0			0	0
Feed pumping	Average flow 101 mgd, 25 ft		0			2600	46800	14040	15000	280100	196070	271910
from FE	TDH		0				0	0			0	0
			0				0	0			0	0
Chemical delivery			0				0	0			0	0
FeCl3	Avg. rate = 2042 lb/hr, pure, Note A.	16000	1120	8944	1126944	160	2880	864	220		0	1132028
Polymer #1	Avg. rate = 421 lb/day, Note A.	18000	1260	77	308000	300	5400	1620	800		0	317080
Polymer #2	Avg. rate = 0 lb/day, Note A.		0		0		0	0			0	0
CaO	Avg. rate 712 lb/hr, Note A	5500	385	3121	140445	2100	37800	11340	1300		0	191270
			0				0	0			0	0
Rapid mix	Takes place in feed pump		0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Flocculation	Eight tanks, total volume	102000	7140			279	5022	1506.6	4100		0	17768.6
	= 207,000 cu ft, G = 40 sec-1		0				0	0			0	0
	time = 68 %.		0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Earth sed basins	Eight basins, active surface 283,000		0			5212	93816	28144.8	4100	1000	700	126760.8
	sq. ft, 68 % of time		0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Dedicated land	Area = 383 acres, 2 subsurface		0			4766	85788	25736.4	3000	2000	1400	115924.4
disposal	sludge injection vehicles		0				0	0			0	0
	operating 11 mos/yr.		0				0	0			0	0
			0				0	0			0	0
Monitoring	People = 2		0			4160	74880	22464	8000		0	105344
			0				0	0			0	0
Operations bldg.	Area = 5,000 sq ft, includes	500000	35000				0	0	20000		0	55000
	offices, laboratory, maintenance.		0				0	0			0	0
			0				0	0			0	0
Miscellaneous			0			0	0	0			0	0
			0				0	0			0	0
		641,500	44,905	12,142	1,575,389	22,717	408,906	122,672	81,920	395,100	276,570	2,510,362

TABLE 10: O & M COSTS-S-7, CHEM. SED. W/CONV. SED. TANKS + TUBE SETTLERS   CHMSEDTS.WK3

OPERATION	BASIS FOR COSTS	Power kwh/yr	Power Dollars	Chemicals tons/yr	Chemicals Dollars	O&M labor hrs/yr	O&M labor Dollars	Admin. & support. Dollars	Maint. matl., Dollars	Fuel, gal/yr	Fuel, Dollars	Total dollars
Feed pumping to FE	Avg. flow 101 mgd, 10 ft TDH		0			2600	46800	14040	15000	112000	78400	154240
			0				0	0			0	0
			0				0	0			0	0
FE basin	Capacity 3900 million gallons		0			540	9720	2916	10400		0	23036
			0				0	0			0	0
Feed pumping from FE	Average flow 101 mgd, 25 ft TDH		0			2600	46800	14040	15000	280100	196070	271910
			0				0	0			0	0
			0				0	0			0	0
Chemical delivery			0				0	0			0	0
FeCl3	Avg. rate = 2042 lb/hr, pure, Note A.	16000	1120	8944	1126944	160	2880	864	220		0	1132028
Polymer #1	Avg. rate = 421 lb/day, Note A.	16000	1260	77	306000	300	5400	1620	800		0	317080
Polymer #2	Avg. rate = 0 lb/day, Note A.		0		0		0	0			0	0
CaO	Avg. rate 712 lb/hr, Note A	5500	385	3121	140445	2100	37800	11340	1300		0	191270
			0				0	0			0	0
Rapid mix	Takes place in feed pump		0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Flocculation	Eight tanks, total volume = 207,000 cu ft, G = 40 sec-1 time = 68 %.	102000	7140			279	5022	1506.6	4100		0	17768.6
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Rectangular clarifiers w/ tube settlers	Eight tanks, active surface 55,000 sq. ft. 68 % of time	98000	6860			4000	72000	21600	8200	1000		108660
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Dedicated land disposal	Area = 383 acres, 2 subsurface sludge injection vehicles operating 11 mos/yr.		0			4766	85788	25736.4	3000	2000	1400	115924.4
			0				0	0			0	0
			0				0	0			0	0
			0				0	0			0	0
Monitoring	People = 2		0			4160	74880	22464	8000		0	105344
			0				0	0			0	0
Operations bldg.	Area = 5,000 sq ft, includes offices, laboratory, maintenance,	500000	35000				0	0	20000		0	55000
			0				0	0			0	0
			0				0	0			0	0
Miscellaneous			0			0	0	0			0	0
			0				0	0			0	0
		739,500	51,765	12,142	1,575,389	21,505	387,090	116,127	86,020	395,100	275,870	2,492,261

Notes

A. Chemicals, dollars/ton	
$FeCl_3$ (pure) =	126
Polymer #1 =	4000
Polymer #2 =	800
CaO =	45
B. Power, dollars/kwh	0.07
C. Labor, dollars/hour, including benefits	18
D. Fuel, dollars/gal	0.7
E. Admin. & supp. mult.	0.3

TECHNICAL MEMORANDUM NO. 5 22-7518-01

May 9, 1993

TO: FILE

FROM: C. ZACHARY FULLER, P.E.
SPENCER B. FORREST

SUBJECT: CHEMICAL TREATMENT WITH SEDIMENTATION

Based on the rating system used in the Amendment No. 4 Report, direct filtration scored better than sedimentation in earthen basins based primarily on total present worth costs, phosphorus (P) removal efficiency and system reliability. The ability to meet the P removal goals mandated in the SWIM Plan is the dominant factor in the Amendment No. 4 recommendations and in the recommendations that were set forth in the results section of Technical Memorandum No. 1 (T.M. No. 1). In the Amendment No. 4 Report, chemical treatment with sedimentation basins was assumed to produce a treatment plant finished water quality of 40 ug/L P at a design overflow rate of about 400 gpd/ft^2. Amendment No. 6 bench scale testing and water quality testing results (T.M. No. 1) indicate that it may be possible to amend the earlier finished water quality and design overflow rate assumptions.

The purpose of this memorandum is to present a detailed example of sedimentation technology using new sedimentation treatment assumptions determined from the bench scale testing results. The basin chosen for this example is Basin S-7 because the ease of comparison with the Amendment No. 4 results since the Basin S-5A analysis has significantly changed in the Amendment No. 6 work due to the incorporation of the ENR Project into the Basin S-5A treatment system. In addition, the low P concentrations in Basin S-7 make it the most promising basin to which sedimentation technology can be applied. Application of this technology to other basins is discussed later in this memorandum.

Bench Scale Testing of Sedimentation

As presented in the bench scale testing section of this report (T.M. No. 1) chemical treatment with sedimentation was simulated with EAA runoff waters in bench scale laboratory experiments. These experiments lead to the following results concerning chemical treatment with sedimentation:

1. Figure 1-11 and Figure 1-14 (Tech Memo No. 1, pages 1-14 and 1-15) indicate that a finished water quality of P as low as 20 ug/L may be feasible with sedimentation technology using either alum or ferric chloride. As shown in Figure 1-14, total

phosphorus (TP) levels of less than 20 ug/L were achieved with ferric chloride. Ferric chloride is the coagulant used in this analysis.

2. Subsequent water quality analyses for turbidity, etc., indicate that the water quality of sampled runoff waters might yield a sedimentation basin design overflow rate of as much as 600 gpd/ft^2. This rate is significantly higher than that assumed in the earlier Amendment No. 4 Report (400 gpd/ft^2).

Sedimentation Technology Example

In comparing direct filtration with sedimentation, the results of T.M. No. 1 of this report state that one can not usually achieve the same level of finished water quality with sedimentation, even when higher coagulant doses are used (T.M. No. 1, page 1-44). The results of bench scale testing of actual Everglades runoff waters confirmed this conclusion: simulated direct filtration consistently "outperforms" sedimentation in regards to finished water quality (measured in both terms of remaining TP and turbidity).

There remains two questions (1) as to the reliability of the sedimentation process to consistently achieve low P levels, and (2) the cost competitiveness of sedimentation with direct filtration. As to costs, it may be possible that sedimentation technology proves cost-competitive when compared to direct filtration technology in terms capital, operations and maintenance (O&M) or total present worth (PW) costs. Therefore, the revised assumptions based on the bench scale testing are used in conceptual sizing of sedimentation with earthen basins. This conceptual process design is then used to derive capital and O&M costs to arrive at a total 20-year PW. PW costs are then compared to costs derived from direct filtration analysis in T.M. No. 4 of this report.

Basis of Design for Sedimentation

Flow equalization basin and treatment plant sizing was determined using the model derived for that purpose as explained in T.M. No. 3. Daily flow and P load data development remain the same as explained for Basin S-7 in T.M. No. 2. Table 5-1 presents the basis of design table for the 1,500 acre flow equalization basin and 170 MGD sedimentation treatment plant sized for Basin S-7.

Table 5-1 Basis of Design for Sedimentation in Earthen Basins

Item	Basin S7
Basin Data	
Flow, million gals	
Maximum annual	90,460
Minimum annual	19,040
Average annual	57,625
Flow, acre-ft	
Maximum annual	277,593
Minimum annual	58,428
Average annual	176,833
P Concentration, mg/L	
Maximum annual	0.171
Minimum annual	0.060
Average	0.112
TSS Concentration, mg/L	
50th percentile	6
Plant Data	
Percent of days on line	65
Percent basin flow treated	63
Flow, mgd	
Maximum	170
Minimum	0
Average	
All days	100
When operating	135
Maximum year	
Total plant flow, MG	56,718
Treatment Plant Influent Pumps	
Number (1 spare)	4
Capacity each pump, gpm	39,349
TDH each, ft	25
Flow Equalization Basin Data	
Surface area, acres	1,500
Maximum water depth, ft	8
Volume, million gals	3,910
acre-ft	12,000
Storage at peak plant flow, days	23
FE Basin Influent pump station capacity, mgd	1,610
FE Basin Effluent/Treatment Plant Influent	
P Concentration, mg/L	
Maximum annual	0.135
Minimum annual	0.047
Average	0.088
TSS Concentration, mg/L	
50th percentile	4

Table 5-1 Basis of Design for Sedimentation in Earthen Basins (continued)

Item	Basin S7
Flow Equalized/Treatment Plant Bypass	Gated Spillway
Chemical addition systems	
Ferric Chloride	
Form	33% Solution
Dose, mg/L as Fe	
Average	20
Maximum	27
Pumps	
Number (1 spare)	2
Capacity, each, gpm	9
Storage tanks	
Volume, gals	400,000
Liner	Rubber
Storage time at peak feed rates, wks	2
Polymer	
Form	Anionic 2% Solution
Dose, mg/L	
Average	0.5
Pumps	
Number (1 spare)	2
Capacity, each, gpm	3
Daily Solution tank, gals	4,500
Storage tanks	Supplied by vendor
Lime	
Form	5% Slurry
Dose, mg/L as CaO	
Average	14
Maximum	20
Slakers	
Number (1 spare)	2
Capacity, each, lbs CaO/hr	1,199
Pumps	
Number (1 spare)	3
Capacity, each, gpm	20
Storage silos	
Silo volume, ft^3	3,000
Storage time at peak feed rates, wks	2

Table 5-1 Basis of Design for Sedimentation in Earthen Basins (continued)

Item	Basin S7
Rapid mixing	Influent-pump mixing
Flocculators	
Number, in parallel	2
Compartments per flocculator	4
Volume per compartment, gal	175,481
Total detention time at average operating flow, mins	15
Velocity gradient, sec^1	
Minimum	25
Maximum	55
Maximum power input per tank, HP	4
Material of construction	Concrete
Sedimentation Basins	
Number of basin banks, in parallel	2
Number of basins per bank	5
Sections per basin	3
Surface area total, ft^2	284,000
Material of construction	Earthen
Overflow rate, gpd/ft^2	600
Effective depth, ft	12
Length, ft	215
Width, ft	44
Length to width ratio	4.9
Detention time at peak flow, hrs	3.6
Forward velocity at peak flow, ft/min	1.0
Dedicated Land Disposal	
Dredging season, mos	11
Sludge production, tons dry solds per year	
Maximum	13,339
Maximum application rate, tons dry solids per acre per year	35.5
Number of sections	7
Area per section, acres	49.0
Sludge disposal trucks	2
Spreading rate, gal/day	120,000
Land requirements, acres	1,876

Conventional Sedimentation with Settling Tubes

The use of sedimentation in earthen basins was initially selected in the alternative analysis due to the large area available for the construction of the basins, the simplicity of the operation, the similarity to the proposed use of rock pits for sedimentation basins and the relative low cost of basin construction. However, it was recognized that without well designed flow distribution, solids removal, and hydraulic control, the performance of the sedimentation basin would be less than that of a conventional clarification system.

In an effort to improve sedimentation treatment reliability, the use of settling tubes within conventional sedimentation basins was briefly evaluated to determine the cost associated with a more conventional clarifier system. This process alteration results in greatly improved control over process hydraulics. Control of process hydraulics is central to P removal efficiency and reliability. The capital cost of sedimentation using settling tubes is presented to allow preliminary comparison of sedimentation technologies with one another and with direct filtration technology presented in T.M. No. 4.

Capital Cost Estimates

Capital costs were derived using the methods explained in T.M. No. 4 of this report. Table 5-2 presents the major components of the capital cost estimate of the sedimentation technology for Basin S-7.

Table 5-2 Sedimentation Technology Capital Costs

Basin S-7 Capital Costs (a)

Process Area/Item	Conventional Sedimentation	Sedimentation with Tube Settlers
Contractor Indirects	$519	$748
Land Acquisition	972	972
Influent Channel	243	243
Yard Development	310	310
Influent Pump Station	3,887	3,887
Water Feed Channel	872	872
Flocculation	2,200	2,200
Chemical Addition	855	855
Sedimentation Basins	1,133	6,732
Dedicated Land Disposal	1,090	1,090
Effluent Channel	962	962
Yard Piping	709	1,023
Electrical/Instruments	1,927	2,779
Central Plant Building	675	675
Subtotal	$16,354	$23,348
Bond @ 1%	164	233
Subtotal	$16,517	$23,581
Engineering @ 15%	2,332	3,391
Land Acquisition @ 10%	97	97
Construction @ 20%	3,109	4,522
Total Treatment Plant Capital Cost	$22,056	$31,592

(a) Thousands of June 1993 dollars.

Cost Estimate Summary

O&M costs were estimated for both the earthen basin sedimentation process and the tube settling sedimentation process. Additional details on the O&M cost estimate are provided in Appendix A-5.

As presented in the T.M. No. 1, the 20-year PW is calculated using the capital cost estimate and O&M cost estimates. Table 5-3 presents total capital cost, O&M estimate and the 20-year PW estimate for the sedimentation examples presented above.

Table 5-3 Estimated Costs for Sedimentation Technologies

Item	Sedimentation in Earthen Basins	Sedimentation with Tube Settlers
Treatment Plant Size (MGD)[b]	170	170
FE Basin Size (acres)[b]	1,500	1,500
Treatment Plant Capital Cost[a]	$22,056	$31,592
FE Basin Capital Cost[a]	$34,571	$34,571
Total Capital Cost[a]	$56,627	$66,163
Total O&M[c]	2,492	2,510
Total 20-year PW[d]	$81,094	$90,806

[a] Thousands of June 1993 dollars.
[b] Based on an assumed 35 percent reduction in TSS and particulate P in the flow equalization basin.
[c] See Appendix A-5 for details.
[d] See T.M. No. 4, page 4-6.

Discussion of Costs

Basin S-7 results indicate that capital costs for sedimentation technology has the potential for capital cost savings (about 10 percent) when compared to direct filtration capital costs (T.M. No. 4, page 4-2). Conventional sedimentation technology may even be more expensive on a capital basis (about 5 percent). Operations and maintenance costs are about equal to O&M cost estimates for direct filtration systems (T.M. No. 4, Appendix C-4). Lower costs of labor for the sedimentation system is offset by the greater chemical costs, resulting in a total 20-year PW that is comparable to the PW cost estimate of direct filtration technology.

Conclusions of Sedimentation vs. Direct Filtration

It was concluded from earlier alternatives analyses (Amendment No. 4 Report) that direct filtration was a potentially more efficient, reliable and cost-effective P removal technology for application to EAA runoff waters. Amendment No. 6 results substantiate this conclusion. The central reasons supporting the original conclusion were founded on the ability of the technology to reach the SWIM Plan goals. The analyses performed in Amendment No. 6 yield the following conclusions and results when comparing sedimentation and direct filtration technology:

1. Direct filtration produces finished water with lower total P and turbidity than sedimentation. For a given chemical dosage, direct filtration is able to produce a TP in the finished waters that is (in some cases) half that of sedimentation.

2. Sedimentation technology is still a potentially attractive P removal technology that should be "co-tested" to the extent that direct filtration technology is researched and developed. The primary advantages of sedimentation are in its ease of operation and potential economic benefits. The findings of this memorandum indicate that it might be cost effective to employ sedimentation in earthen basins. Furthermore, the application of tube settlers would greatly improve reliability and operational control but come at increased capital cost that may not make sedimentation economically attractive when compared to direct filtration.

3. Brown and Caldwell believes that conventional sedimentation with tube settlers is the superior of the two sedimentation technologies. Direct filtration is preferred over either sedimentation technology because of its ability to produce very low P levels in the finished waters. In addition, additional piloting of sedimentation processes may indicate what is currently believed: the process of sedimentation has the potential to be affected by hydraulic instabilities that may "upset" the sedimentation process. The flows and P load patterns within the EAA runoff are historically very sporadic and dynamic--exhibiting a "pulsing" behavior. While flow equalization does decrease this irregular hydraulic and P load behavior, it is still likely that any treatment system will have to respond to the historical pattern (more or less) of flows and P-loads. It is the ability to meet the P-removal goals of the SWIM Plan that is of greatest concern. The laboratory results have indicated that sedimentation can meet the goals, however, this has yet to be shown on an increased scale. In contrast, direct filtration technology, following the full-scale Wahnbach, Germany model, has demonstrated that the process can be a reliable low-level P removal technology.

4. In addition, costs analyses including the revised assumptions of finished water quality (from 40 ug/L P to 20 ug/L P) and sedimentation basin overflow design rate (from 400 gpd/ft^2 to 600 gpd/ft^2) from Amendment No. 4 Report analyses result in about a 10 percent capital cost difference.